Some Aspects of the International Experience of Plant Variety Protection

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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

[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.

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

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. Data on the dependent variable, the number of plant variety protection certificates granted in country i in time t, are derived from a database of protected varieties put together by the authors[3]. The explanatory variables are: value of agricultural output, lagged values of public and private R&D expenditure, an index of IPR regime strength, the number of years since PVP legislation was introduced, and a variable representing the spill-ins of R&D efforts from other countries. The key hypothesis is, of course, that stronger PVP regimes lead to the development and protection of more varieties. The value of agricultural output is included as a scaling variable, since it is expected that countries with larger agricultural sectors will have more varieties generated. As PVP regimes become more mature, the benefits from protection might be more easily perceived. A description of the variables and the sources of data for each are given in Annexure 1.

Count Data Methods

In modelling the effects of R&D spending and PVP legislation upon PVP certificate application, it is important to recognize that data on the dependent variable are different from data in typical

[3] A database on protected varieties in each country was put together using data from UPOV and the Plant Variety Protection authorities of individual countries.

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 most fundamental of these is the Poisson regression model. Suppose G_{it} represents the number of PVP grants applied for in country i in year t. The G_{it} are assumed to be independently distributed as Poisson, with parameters λ_{it}, with the λ_{it} specified as functions of the set of explanatory variables, x_{it}, discussed above (Hausman et al.: 1984; Cincera: 1997):

$$\lambda_{it} = \exp(x_{it}\beta) = \exp(\beta_0 + \sum_{t=1}^{3} \beta_{1t-t} \log(PUBRD_{it-t}) + \sum_{t=1}^{3} \beta_{1t-t} \log(PVTRD_{it-t}) + \delta_v \log(agval_{it}) + \delta_p \log(strng_{it}) + \delta_a \log(age_{it}) + \delta_s \log(spill_{it})) \quad (1)$$

In (1), PUBRD and PVTRD are public and private R&D expenditures, *agval* is the value of agricultural output, *strng* is the strength of the IPR regime, *age* is the number of years that have elapsed since IPR regime introduction, and *spill* is the spill-in variable. The number of lags on the R&D variables is restricted to three because of data availability, and in order to limit parameter proliferation.

The conditional expected value of G_{it} is given by

$$E(G_{it} | \beta, x_{it}) = \lambda_{it} \quad (2)$$

For this basic Poisson model, λ_{it} is also the conditional second moment. This equivalence between the first two moments is a restriction of the empirical generality of the basic model. With a cross-sectional element involved, this becomes a particularly strong restriction of, since unobserved heterogeneity is likely to cause ‘overdispersion’, or the conditional mean being exceeded by the conditional variance (Winkelmann and Zimmermann: 1995). For example, in our IPR context, the quality of the human capital or the investment climates in particular countries may cause the agricultural research sectors in them to be more prone to developing and registering IPR protection for new varieties than others. Just as in the linear panel case, both fixed and random effects versions of the Poisson model are available in the literature. These panel methods allow for the control of unobserved heterogeneity, and thereby also allow for overdispersion. In the fixed effects case, this amounts to a replacement of β_0 in (1) above by individual-specific intercepts, β_i. Unlike the linear panel case, however, least squares using deviations from group means is not applicable, and a conditional maximum likelihood method developed by Hausman, Hall and Griliches (1984) must be employed. In the random effects case, also developed by the same authors, (1) is rewritten as

$$\lambda_{it} = \exp(x_{it}\beta) + u_i \qquad (3)$$

In (3), u_i is assumed randomly distributed across countries, with exp (u_i) having a gamma distribution with parameters (θ,θ), so that E (exp (u_i)) = 1, and the variance V(exp(u_i)) = 1/ θ. Given this set up, the u_i can be integrated out of the joint density of the IPR grants random variables and the u_i, setting up a likelihood function that can be estimated by Maximum Likelihood. Further details regarding both the fixed and random effects models are available in Hausman, et. al. (1984) and Cameron and Trivedi (1998). These are now well-known methods and hence we do not repeat them in much detail here.

The choice between fixed and random effects methods is an important one, and Cameron and Trivedi (1998) report that there is mild preference in the literature for fixed effects. The fixed effects approach of course has the advantage of not requiring the assumption of zero correlation between cross-sectional heterogeneity effects and the regressors. However, in the fixed effects case, time-invariant variables are not identified. While our model does not contain any strictly time-invariant variables, the patent strength variable varies only marginally over time for most countries, and in the case of a few, is fixed over the duration of the sample. Given that the effect of the patent strength variable is of key importance in our first principal hypothesis, the random effects estimator described above becomes a natural choice. We therefore adopt this approach, and do not make further reference to the fixed effects case.

Results

Table-1 below presents results from two alternative models. The overall Poisson model does not account for individual heterogeneity, 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

	Overall Poisson		Random Effects Poisson	
	Coeff.	**Std.Err.**	**Coeff.**	**Std.Err.**
Constant	-0.95***	0.28	-0.95	0.69
Log(agval)	0.63***	0.01	0.59***	0.06
Log(PVTR&D$_{t-1}$)	0.16***	0.02	0.25***	0.02
Log(PVTR&D$_{t-2}$)	-0.02	0.02	0.04***	0.02
Log(PVTR&D$_{t-3}$)	-0.08***	0.02	-0.01	0.02
Sum of log(PVTR&D)	*0.06*		0.28	
Log(PUBR&D$_{t-1}$)	0.45***	0.04	0.50***	0.11
Log(PUBR&D$_{t-2}$)	0.07	0.06	0.14	0.16
Log(PUBR&D$_{t-3}$)	-0.77***	0.05	-0.67***	0.08
Sum of log(PUBR&D)	-0.25		-0.03	
Log(age)	0.88***	0.02	0.89***	0.05
Log(spill)	-0.35***	0.02	-0.25***	0.02
Log(strng)	2.36***	0.10	2.37***	0.48
Log Likelihood	-7151		-3079	
***significant at 1% level of significance.			$R^2_{PEARSON}$ =0.67	$R^2_{DEVIANCE}$ =0.64

The overall fit of the models 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. The main hypothesis is confirmed immediately even at the 1% significance level, that stronger PVP legislation results in an increase in the grant of PVP certificates. A 10% increase in the value of the index[4], results in a 23.7% increase in the number of varieties offered for protection. For countries with relatively weak PVP regimes in our sample, like Canada, Finland and Ireland, this implies that moving up closer to the OECD average for regime strength could imply a significant improvement in varietal development and protection. The significant positive coefficient on the *age* variable reveals that, with the passage of time, PVP regimes gather momentum and result in registration of more new certificates. Note also that the *age* variable is picks up some of the effects that would have been produced by a traditional trend variable. As expected, the value of the agricultural sector has a positive and significant coefficient, implying that more varieties are protected when the market is larger.

The significant negative coefficient on the spill-ins variable is somewhat puzzling. Taken at face value, it indicates that an exogenous increase in the R&D stock of the other countries in the

[4]Given the nature of construction of the index, which takes into account several different features of the IPR regime in a country, it is not possible to give an intuitive interpretation of what a certain percentage increase in the value of the index implies. However, an increase in the value of the index does constitute strengthening of the IPR regime.

sample results in a small but statistically significant reduction in varietal protection in the home country. Now, the second part of this paper indeed argues that transferability of varieties across countries with PVP protection is very limited. Thus a statistically insignificant coefficient for this variable would not have been very surprising. Significant negative coefficients for diffusion variables have also been found in the patents-R&D literature, *e.g*. Crepon and Duget (1997). There, it has been interpreted as evidence of competitive, as opposed to complementary, knowledge production within the nation. However, in a country-level panel with production primarily for national markets, such as ours, such an interpretation appears invalid. A possible answer to the puzzle is that the use of current stock of PVP certificates is a less than perfect representation of spillover possibilities.

The overall Poisson model results in somewhat disturbing coefficients for the lagged values of the R&D expenditure variables. It is conventional in the patents-R&D literature to look at the sum of the sum of the lagged R&D coefficients in addition to the individual ones. These sums from the overall Poisson model indicate that the effect of private sector R&D spending on PVP protection is positive but very marginal (a 10% increase over the 3 years resulting in only 0.6% increase in grants), while it is negative for public sector R&D! However, results from the more general random effects Poisson model are more plausible. Coefficients of 0.25, 0.04 and –0.01 for the three private sector lag variables demonstrate that much of the impact of private sector R&D comes early on in the varietal development and protection process, and tails off quickly. Thus a 10% increase in the previous year's private R&D expenditure is seen to increase the protection of new varieties by 2.5%, while a similar increase in t-2 generates only 0.4% more grants in t. While a negative (though marginal) coefficient for the third lag is counterintuitive, this has been a common enough feature in the patents-R&D literature as well. In fact, many of these studies report a U-shaped structure (Hausman, et. al (1984), Cincera (1987)). Hausman, et. al (1984) speculate that later lags in these models might be influenced by lag-truncation effects, i.e., the uncaptured effects of R&D influences from before the sample period.

The coefficients on the lagged public R&D variables are more problematic, however. While a significant elasticity of 0.5 is observed in t-1, the effects are insignificant for t-2, and become significant and negative by t-3, resulting in a coefficient sum of –0.03. Again, lag truncation may be playing an important part here. The overall conclusion is that increased public R&D has double the varietal-protection impact that an equivalent spending on private R&D does, in the following year. Effects tail off quickly, although they may be lingering on enough to accumulate and create a truncation bias.

Transferability of Varieties

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[5]. 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.

[5] From a breeder's point of view, what matters is not so much the absolute size of the market but the appropriability of returns from marketing a variety in country j. This may depend on the level of enforcement of PVP and the associated costs of enforcement. Thus, a breeder's decision to protect a variety in other countries will depend not only on the rights granted but also on the feasibility of enforcing them.

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[6]. 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 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

[6] Article 3 of the UPOV 1978 Convention provides: “Without prejudice to the rights specially provided for in this Convention, national and legal persons having their registered office in one of the member-states of the Union shall in so far as recognition and protection of the rights of the breeder are concerned, enjoy in other member-states of the Union the same treatement as is accorded by the respective laws of such States to their own nationals, provided that such persons comply with conditions and formalities imposed on such nationals”. (UPOV: 1978). The TRIPs Agreement makes a similar provision for ‘national treatment’.

have been protected in more than one country. These are (a) provisions regarding denomination of varieties and (b) provision regarding "right of priority"[7]. 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

[7] While we do not discuss these provisions in detail here, the implication of these provisions is that, except in a very limited number of cases, a variety will have the same denomination in all member-states. This facilitates the identification of varieties that have been protected in several member-states. The data in Table-2 is based on grants made in each of the 30 UPOV countries for these six crops since the inception of PVP legislation.

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[8] (3) Europe (4) North America (5) South America.

A matrix of inter-regional flows of protected varieties is presented in Annexure-2. 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:

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

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.

Annexure-2 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

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

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 Annexure-3, which lists the contribution of important pairs of EU countries to the intra-Europe flow. Annexure-3 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[9].

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 Annexure-2 and Annexure-3 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

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[9] 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.

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. No variety can be marketed in the European Economic Area (EEA) unless it has been inscripted in the catalogue, which in turn requires that the variety be tested for DUS[10] and VCU[11] and inscripted in at least one national catalogue. It also requires that a "maintainer" be designated for the variety. This arrangement has the effect of preventing piracy in the organised seed production sector. At the same time, inscription in the European catalogue allows a variety to be freely marketed in all EEA countries which drastically reduces the cost of that would otherwise be involved in securing separate regulatory approvals in a number of markets. The catalogue, therefore, provides relatively easy access to a large market, while discouraging potential IPR infringement. Under the mandatory system of seed certification in EU countries, fields are inspected, tests (for purity, germination etc.) are run and seeds are sold with a certification tag attached to each bag. The tags are numbered and the mention the name of the variety and the producer. If records are kept, the breeder knows exactly the quantities of his variety sold. Certification effectively curbs the evasion of royalty/license fee payment to the breeder[12].
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[13] 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

[10] Distinctness, Uniformity and Stability.
[11] Value in Cultivation and Use.
[12] In the United States, seed certification is not compulsory. The U.S. PVP legislation, however, allows the breeder of a protected variety to specify that only certified seed of his variety be sold. This provision has not been extensively used by titleholders in the U.S.
[13] Small farmers are exempted. Small farmers for the payment of royalty to breeders on protected varieties are defined as farmers who do not grow plants on area bigger than the area, which would be needed to produce 92 tonnes of cereals. (Article 14(2) of the Council Regulation (EC) no. 2100/94 of 27 July 1994 on Community Plant Variety Rights of the Council of the European Union).

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 Annexure-2 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 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[14] in different countries (Evenson: 2000). The large scale transfers of germplasm accessions, breeding lines and even finished varieties between the International Agricultural Research Centres (IARCs) and the National Agricultural Research Systems (NARS) of developing countries is well documented (SGRP: 1996). These flows completely dwarf the flows of 'finished' protected varieties between countries. The scale of these transfers also suggests that flows of these elements of plant genetic resources are more important to the success of a country's plant breeding programme than the transfers of protected varieties. But the flows of these elements of plant genetic resources are not subject to IPRs and are governed

[14] Such exchanges are probably widespread between private sector institutions as well as consequence of foreign direct investment and technical collaborations, though no data on the magnitude of such flows is available.

by a different regime. The most important element of this regime is the International Undertaking on Plant Genetic Resources (IUPGR) negotiated under the auspices of the FAO, which (till quite recently) was based on the principle that plant genetic resources are a 'common heritage of mankind' that should be freely exchanged without restrictions. The spread of PVP and the application of IPRs to finished products of plant breeding and the provisions of the Convention on Biological Diversity are leading to fundamental and far-reaching changes in the international regime that governs the exchange of plant genetic resources (not currently subject to IPRs). The most crucial impact of PVP may, therefore, lie not in the transfer of protected varieties that it facilitates, but in serving as a trigger for these important institutional changes.

Foreigners' Share of PVP Certificates

The data on the share of foreigners in PVP grants was provided by the World Intellectual Property Organisation (WIPO) in Geneva, Switzerland. The data set covers the period from 1975-1998 and provides details of the PVP applications and grants in all countries with PVP legislation (irrespective of whether they are UPOV member-countries or not). The year wise figures of applications/grants are further broken up into applications/grants to (1) residents (2) non-residents (foreigners). The break up of grants to non-residents by country of origin of applicant is also provided. The crop wise break up of grants to foreigners is however, not available.

During the period 1975-1997 a total of 30,265 PVP grants were made to foreigners in 45 countries, which constituted 36.75% of all the grants made. The cumulative proportion of grants made to foreigners increased from 29% to 37% over this period. The countries making the largest number of grants to foreigners ("recipient countries") and the countries securing the largest number of grants ("donor countries") were the following:

Donor countries			Recipient countries		
Country	Number of grants acquired in foreign countries	Share of total grants made to foreigners	**Country**	Number of total grants made to foreigners	Share of total grants made to foreigners
Netherlands	7887	26.06%	Netherlands	4207	13.90%
Germany	6488	21.41%	Germany	3863	12.76%
France	4392	14.51%	France	3011	9.95%
United States	4270	14.11%	United Kingdom	2926	9.67%
United Kingdom	1560	5.15%	United States	2651	8.76%
Denmark	1239	4.09%	Denmark	2284	7.55%
Total	25836	85.37%	Total	18942	62.59%

Interestingly, the top six ‘donor’ and ‘recipient’ countries were the same and they were all developed countries. They were also the leading countries in terms of the total number of grants made. There was, however, considerable variation in the grants made to foreigners in different regions. In Table-3, the WIPO data has been recast on a regional basis with columns representing regions making grants and rows representing regions securing grants.

Table-3: PVP Grants to Foreigners by Regions

Granting region → / **Applicant region ↓**	**Africa**	**Asia**	**Australia**	**Europe**	**North America**	**South America**	**Total**
Africa	-	-	5 *(0.42%)*	17 *(0.07%)*	2 *(0.06%)*	1 *(0.13%)*	25 *(0.08%)*
Asia	77 *(8.29%)*	75 *(4.24%)*	50 *(4.23%)*	605 *(2.6%)*	253 *(8.46%*	20 *(2.75%)*	1080 *(3.56%)*
Australia	67 *(7.21%)*	5 *(0.28%)*	134 *(11.33%)*	131 *(0.58%)*	147 *(4.91%)*	37 *(5.10%)*	515 *(1.70%)*
Europe	566 *(60.99%)*	1572 *(88.9%)*	751 *(63.5%)*	18718 *(82.5*	2299 *(76.9)*	290 *(40%)*	24196 *(79.94%)*
North America	218 *(23.49%)*	108 *(6.10%)*	240 *(20.3%)*	3196 *(14.09)*	291 *(9.73%)*	357 *(49.24%)*	4410 *(14.57%)*
South America	-	8 *(0.45%)*	2 *(0.16%)*	6 *(0.02%)*	3 *(0.10%)*	20 *(2.75%)*	39 *(0.12%)*
Total	928 *(100%)*	1768 *(100%)*	1182 *(100%)*	22673 *(100%)*	2989 *(100%)*	725 *(100%)*	30265 *(100%)*
Percentage to total grants	55.77	20.82	53.50	38.83	29.48	45.22	36.75
Figures in parentheses are percentages to column totals							

Grants made to foreigners varied from 20% in Asia to 55.77% in Africa. In each granting region more than 85% of the grants were made to applicants from Europe and North America. Grantees from Europe and North America accounted for 93% of PVP grants made to foreigners. Europe made the largest number of grants to foreigners (22673) and this constituted 38.83% of all grants made by European countries. However, 82.5% of grants made to foreigners by European countries accrued to other European countries. This reinforces the conclusion from the previous section that large-scale inter-country movement of protected varieties is mainly a European phenomenon. Grants made by Europe and North America *to* Europe and North America constituted an extra-ordinarily high proportion of (80.56%) of all grants made to foreigners.

The acquisition of PVP certificates by foreigners in developed and developing countries is summarised in Table-4.

Table-4: PVP Grants to Foreigners in Developed and Developing Countries

Granting countries → / **Applicant countries ↓**	**Developed countries***	**Developing countries****	**Total**
Developed countries	26798 *(88.54%)*	2591 *(8.56%)*	29389 *(97.10%)*
Developing countries	654 *(2.16%)*	222 *(0.73%)*	876 *(2.89%)*
Total	27452 *(90.7%)*	2813 *(9.3%)*	30265 *(100%)*

***** Developed countries: Austria, Australia, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Israel, Italy, Japan, Luxembourg, the Netherlands, Norway, New Zealand, Sweden and United States. The certificates issued by the Community Plant Variety Office were included under developed countries with grants to non-EU applicants representing grants to foreigners.

**Developing countries: Argentina, Bulgaria, Brazil, Chile, China, Colombia, Czechoslovakia, Czech Republic, Ecuador Hungary, India, Slovakia, South Korea, Lithuania, Mexico, Mongolia, Paraguay, Poland, Portugal, Romania, Russia, Soviet Union, South Africa, Trinidad and Tobago, Ukraine, Uruguay, Vietnam, Yugoslavia, Zimbabwe.

*Figures in parentheses are percentages to total grants to foreigners (30265)

Developing countries have secured a very small fraction (2.38%) of grants to foreigners made in developed countries. Grants secured by developing countries in other developing countries are also negligible. At the same time grants made by developing countries to foreigners are a small proportion of total grants made to foreigners by all countries.

Table-4 illustrates the extremely limited participation by developing countries in the international IPR system for plant varieties. Few of their innovations get protected in developed countries. This implies that the potential for obtaining rents on protected varieties from developed countries is rather limited, even though developing countries are in many instances large contributors of plant genetic resources to breeding programmes of developed countries. At the same time developing countries receive only a small fraction of the innovations of foreigners. These factors may explain the extreme reluctance of many developing countries to introduce PVP systems. If the decisions of foreigners to seek protection for their varieties were based on commercial considerations, then it would appear that developing countries offer limited appropriability of returns from the marketing of new (protected) varieties. This in turn could be due to the limited size of markets or due to low levels of enforcement of IPRs that limit appropriability, or both.

With 37% of all PVP grants accruing to foreigners, it is clear that national PVP systems elicit a significant response (in the aggregate) from foreigners seeking to protect their new plant varieties. But the distribution of foreigners' activity in PVP is highly skewed with most grants to foreigners being made by European and North American countries to breeders from other European and North American countries.

Determinants of Foreigners' Participation in the PVP System

With the exception of East European (erstwhile communist countries) many developing countries such as Chile, Colombia, Ecuador, South Korea, and South Africa have a large proportion of grants accruing to foreigners. But interestingly, several developed countries (e.g. Denmark, Switzerland, Belgium, Canada, Finland, Ireland etc) also have a high proportion of grants accruing to foreigners. While there is considerable variation in the trend between countries, in general the share of grants accruing to foreigners appears to have increased over time in developing countries, while it appears to have decreased in several developed countries. Clearly, the reliance on plant varieties bred by foreigners is not a feature of developing countries alone.

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 data sources for the variables are summarised in Annexure-4. 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					
DependentVariable: 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:

$$CUMSHAREit = Constant + b_1 \, Ln\,(MARKET)_{it} + b_2 \, Ln\,(PATENT)_{it} + b_3 \, INTERACTION_{it} + b_4 Ln\,(GBRDPP)_{it} + b_5 PVPAGE_{it} + b_6 EFI_{it}$$

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.

Stronger intellectual property rights may encourage foreigners to seek more PVP grants. However, its impact on the share of foreigners is ambiguous. If stronger PVP creates more incentives for domestic breeders than it does for foreign breeders, the share of foreigners could decline, even though the number of grants to them may increase. The overall impact of strength of IPR protection on the cumulative share of foreigners is given by:

$$\frac{\delta CUMSHARE}{\delta \, Ln\,(PATENT)} = b_2 + b_3 * Ln\,(MARKET)$$

The overall impact may be positive or negative and would be influenced by the size of the market. Similarly, the impact of the market size variable on the share of foreigners is given by:

$$\frac{\delta CUMSHARE}{\delta \, Ln\,(MARKET)} = b_2 + b_3 * Ln\,(PATENT)$$

While larger markets may encourage greater foreign participation in the acquisition of PVP grants, its impact on the share of foreigners depends on the relative impact of PVP on domestic and foreign breeders. As already noted, the existence of a large domestic research system may offer certain advantages to foreigners for undertaking adaptive research in terms of availability of collaborators, access to germplasm etc. But as a larger domestic research system also implies that foreigners will face greater competition from domestic public and private sector institutions/companies, it is more likely to have a negative impact on the *share* of foreigners in PVP grants. The share of foreigners can generally be expected to increase with the age of the PVP legislation, especially if administration and enforcement of PVP improve over time.

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. However, both fixed effects and random effects specification were tried out and the random effects specification was also chosen on the basis of the Hausman test for fixed versus random effects. The results of the estimation, which were done, using LIMDEP, 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 initial estimations of the model revealed the presence of a high degree of first order autocorrelation of the residuals (the estimated autocorrelation of the residuals was 0.58). In order to adjust for autocorrelation, the dependent and independent variables were transformed using the Prais-Winsten procedure and the coefficients were re-estimated[15].

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[16].

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:

$$\varepsilon_{IPR} = \frac{\delta CUMSHARE}{\delta PATENT} * \frac{PATENT}{CUMSHARE} = \frac{\delta CUMSHARE}{\delta Ln(PATENT)} * \frac{1}{CUMSHARE}.$$

$$= [b_2 + b_3 * Ln\ (MARKET)]*(1/CUMSHARE)$$

$$= [0.4109 + (-0.07424x15.985)]*(1/0.5583) = -1.39$$

[15] On re-estimation, the autocorrelation of the residuals fell to 0.16.

[16] The cumulative share of residents in PVP grants = 1-cumulative share of foreigners in PVP grants. Therefore, a panel random effects regression using the cumulative share of residents as the dependent variable gives exactly the same coefficients (except for the constant term) but with the opposite signs. The absolute values of the elasticities are, however, not the same as the elasticities in this case depend on the value of the dependent variable. As the shares of residents and foreigners are not the same, the absolute values of the elasticities are different.

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:

$$\varepsilon_{MARKET} = \frac{\delta CUMSHARE}{\delta MARKET} * \frac{MARKET}{CUMSHARE} = \frac{\delta CUMSHARE}{\delta Ln\ (MARKET)} * \frac{1}{CUMSHARE}.$$

$$= [b_1 + b_3 * Ln\ (PATENT)] * (1/CUMSHARE)$$

$$= [0.078 + (-0.07424 x 1.323)] * (1/0.5583) = -0.036$$

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).

Conclusion

Plant variety protection has come on the policy agenda of developing countries mainly as a consequence of the provisions of the TRIPs Agreement. The large potential loss of sales for developed country firms due to the absence of IPRs in developing countries was an important argument for the inclusion of "trade-related IPRs" in the Uruguay Round. At the same time a key rationale advanced for the introduction in developing countries was that it would facilitate access to improved plant varieties bred in other (developed) countries that were increasingly getting protected by some form of IPRs. The evidence examined in this paper shows that the incidence of multi-country protection of plant varieties in countries with PVP (mostly developed countries) has been extremely limited. This implies that the direct transfer of protected varieties has been limited even between developed countries that offer fairly high standards of enforcement of breeders' rights. Most transfers of protected varieties have taken place between a limited number of EU countries, where special features of the seed regulatory system have facilitated such transfers. Given the location-specificity of plant varieties, the limited international exchange of plant varieties is not surprising. But it has two important implications. Firstly, developing countries that introduce PVP legislation may find that there are no large stocks of suitable "innovations" that they can access as a result of PVP. The inflow of protected varieties from other countries is not likely to be significant. Secondly, the "loss of sales due to piracy" argument may not apply to plant varieties (in the way in which it may apply to industrial products). Empirical evidence provides very little support to the hypothesis that PVP serves as an instrument facilitating the transfer of varieties across countries.

While the role of PVP in facilitating the international exchange of protected varieties has been limited, it does elicit a significant response from foreigners seeking to protect their plant varieties. Together with the limited incidence of multi-country protection, this suggests that investment and collaboration activities of foreigners (that may also involve adaptive research) may be the most important mechanism for the transfer of breeding materials or technology. PVP must be seen, therefore, primarily as an issue affecting investment rather than trade. Developing countries have so far played a very limited role in the international PVP system, both as recipients and donors of innovations. This may explain the reluctance of a number of developing countries to introduce PVP legislation. An analysis of the determinants of foreigners' participation in PVP systems shows that it is strongly influenced by the size the market, strength of IPRs, the size of the domestic research system and the openness of the economy. There are lessons here for developing countries. Firstly, if developing countries want to encourage the transfer of advanced breeding material from other countries, a PVP system alone may not be sufficient. Much of these transfers are likely to an adjunct to foreigners' participation in the domestic seed industry and research. Therefore, policies, which determine how open an economy is to trade, investment or collaborations are also very important. Secondly, there is evidence to suggest that the incentive effects of PVP are stronger for domestic breeders, at least in the presence of significant domestic research capability. For developing countries with large agricultural research systems, fears of domination by foreign IPRs holders may be unfounded. This may also constitute a strong reason for introducing PVP.

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Annexure -1

Data Sources used for Estimation of PVP Certificates -R&D Relationship

Variable	Description	Data Source
G_{it}	Number of PVP certificates	Taken from the database on protected varieties in each country
$PVTRD_{it}$	Private agricultural R&D expenditure	The nominal private agricultural R&D expenditures in national currencies at current prices were taken from the OECD Basic Science and Technology Statistics (BSTS) for all the countries in the sample (OECD: 1999a). The series used was the "Business Enterprise Research Expenditure" (BERD) series for the sector "Agriculture, Forestry and Fisheries". No further breakdown of expenditure within this sector was available. These figures were converted into 1998 constant prices using OECD's GDP deflator (1998 =100) and then into US dollars (in millions) using the Purchasing Power Parity (PPP) exchange rates (using the OECD's PPP conversion tables).
$PUBRD_{it}$	Public R&D expenditure	The nominal expenditure figures in national currencies at current prices were taken from the OECD Basic Science and Technology Statistics (OECD: 1999a). The series used was "Government Budgetary Outlays on Agricultural R&D" (GBOARD) for the socio-economic objective "Agriculture". These figures were converted into 1998 constant prices using OECD's GDP deflator (1998 =100) and then into US dollars (in millions) using the Purchasing Power Parity (PPP) exchange rates (using the OECD's PPP conversion tables).
$AGVAL_{it}$	Value of agricultural production	These figures were obtained from the OECD's Economic Accounts for Agriculture for member-countries for 1999 (OECD: 1999b). The figures which were in national currencies in current prices were first converted into constant terms (1998 = 100) and then into US dollars in PPP terms using the same procedure as explained above for private agricultural R&D expenditure.
$STRNG_{it}$	Index of strength of IPR protection	The IPR index developed by Ginarte and Park (1997) was used to represent the strength of IPR protection. This index is based on five features of IPR laws in each country (1) Coverage of protection (2) Membership of international IPR conventions (3) Loss of patent protection (threat of forfeiture of patent rights) (4) Enforcement of rights and (5) duration of protection.
AGE_{it}	Age of PVP legislation	Source:UPOV
$SPILL_{it}$	Spillover effects plant breeding R&D in other countries	PVP certificates granted in other countries included in the sample.

Annexure-2

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%

Annexure-3: 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.

Annexure-4

Data Sources for Poisson Panel Regression on PVP grants Accruing to Foreigners

Variable	Description	Data Source
$NRGRANT_{it}$	PVP grants made to foreigners	The data on grants to foreigners in each country in each year was available directly from the data set provided by WIPO.
$MARKET_{it}$	Size of the commercial market for agricultural inputs	Three alternative variables were considered for representing the size of the commercial market for agricultural inputs: 1. <u>Volume of Cereal Production (CEREAL)</u>: The volume of cereal production (in millions of tons) in the countries included in the sample was taken from the FAO's Agricultural Statistics Database (FAOSTAT: 1999). 2. <u>Value of Final Crop Output (AGVAL)</u>: These figures were obtained from the OECD's Economic Accounts for Agriculture for member-countries for 1999 (OECD: 1999b). The figures which were in national currencies in current prices were first converted into constant terms (1998 = 100) and then into US dollars in PPP terms using the same procedure as explained above for private agricultural R&D expenditure. 3. <u>Value of Inputs Consumed in Agriculture (INPUTS)</u>: These figures were also obtained from the OECD's Economic Accounts for Agriculture (OECD: 1999b). The figure for "Intermediate Consumption" included inputs of farm origin, manufactured inputs and other intermediate inputs consumed in the crop sector and the animal sector. These figures, which were in national currencies in current prices, were also first converted into constant terms (1998 = 100) and then into US dollars in PPP terms using the procedure described above.
$GBRDPP_{it}$	Variable indicating size of the domestic research system.	One indicator of the size of the domestic research system is the total expenditure on agricultural research by public and private sector institutions. Data on private sector agricultural research expenditures was not available on a consistent basis for a number of countries included in the sample. "Government budgetary outlays on R&D" for the socio-economic objective agriculture were used as an indicator of the size of the domestic research system. The nominal expenditure figures in national currencies were taken from the OECD Basic Science and Technology Statistics (OECD:1999). These figures were converted into 1998 constant prices using OECD's GDP deflator (1998=100) and then into US dollars in (in millions) using Purchasing Power Parity (PPP) exchange rates (using the OECD's PPP conversion tables)
IPR_{it}		The IPR index developed by Ginarte and Park (1997) was used to represent the strength of the IPR protection.
EFI_{it}		The economic freedom index developed by the Fraser Institute in Canada (Gwartney et al.: 2001) was used as an indicator of the openness of the economy. This index is derived by assigning scores to individual countries on 21 components in the following seven major areas: (1) Size of Government (2) Economic structure and use of markets (3) Monetary policy and price stability (4) Freedom to use alternative currencies (5) Legal structure and security of private ownership (6) Freedom to trade with foreigners (7) Freedom of exchange in capital markets. These indicators broadly cover the areas of reliance on markets, sound money, legal security of property rights, enforcement of contracts and free trade. The aggregate scores for each country lie in the interval 0 to 10 with 10 representing maximum economic freedom. This index has been used in many empirical studies.