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Modelling Economic Returns to Plant Variety Protection in the UK

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Abstract. This paper attempts an empirical assessment of the incentive effects of plant variety protection regimes in the generation of crop variety innovations. A duration model of plant variety protection certificates is used to infer the private appropriability of returns from agricultural crop variety innovations in the UK over the period 1965-2000. The results suggest that plant variety protection provides only modest appropriability of returns to innovators of agricultural crop varieties. The value distribution of plant variety protection certificates is highly skewed with a large proportion of innovations providing virtually no returns to innovators. Increasing competition from newer varieties appears to have accelerated the turnover of varieties reducing appropriability further. Plant variety protection emerges as a relatively weak instrument of protection.

Keywords. Intellectual property rights, plant variety protection, appropriability, economic returns

JEL-codes. Q16, C41

1. Introduction

Crop variety innovations have been one of the key determinants of agricultural productivity growth (Evenson and Gollin, 2001). Over the last hundred years, plant breeding research has taken place in an institutional setting – that is innovations have been the result of investments in plant breeding made by public and private sector institutions. In the UK, the post-1985 period has been a period of significant institutional change in the organisation of agricultural research, with greater emphasis being placed on the role of the private sector, especially for "near market" research. The response of private sector investment to institutional and policy change can be expected to be significantly influenced by the appropriability of economic returns from innovation afforded by existing intellectual property rights (IPR) regimes (e.g., the effectiveness of plant variety protection systems in the case of crop varieties). The incentive effects of IPR regimes and their impact on the generation of innovations are, therefore, a major concern for policy.

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These concerns have been further sharpened over the last decade by two developments – the first is that a number of studies including a major study by DEFRA (DEFRA, 2003) have highlighted concerns about the sharp slowdown in the growth of total factor productivity (to about 0.26% per annum) in UK agriculture since the mid-1980s. These studies have explored several potential causes of this slowdown in TFP growth including the role of domestic and foreign agricultural innovations. The key policy question that arises is whether incentives for innovation provided by current institutional arrangements for agricultural research are adequate. A considerable amount of anecdotal evidence appears to be available regarding the declining enthusiasm of the private sector for conventional plant breeding on account of low appropriability (e.g., Monsanto's decision to withdraw from conventional plant breeding in the PBI). The second key development is the increasing importance of innovations based on agricultural biotechnology. The application of biotechnology to agricultural innovations calls for investments of a much higher order of magnitude than that required for conventional plant breeding. With the private sector playing a dominant role in this area, stronger forms of protection appear to be required for stimulating innovations based on biotechnology. Any policy designed to encourage agricultural innovation needs to take into account the emergence of agricultural biotechnology.

Although the UK and other EU countries have been pioneers in establishing IPR systems for plant variety innovations (and these systems have become well established over the last four decades), there have been no systematic studies on the impact of IPR regimes and other institutional arrangements on the generation of agricultural innovations. This paper will focus on appropriability issues. Much of the current debate regarding the appropriate IPR regime for promoting agricultural innovations (e.g., plant variety protection versus patents) revolves around the question of appropriability of economic returns afforded to innovators under different regimes. This paper will attempt a quantitative estimation of the returns appropriated by innovators in the UK from variety innovations using duration models derived from the behaviour of economic agents. This will provide an empirical basis for assessing the incentives for innovation provided by IPR systems over the period of the study, which has hitherto been lacking. The analysis will address the question of whether there is an economic case for stronger IPR regimes to stimulate crop variety innovations. The empirical application will be to crop variety innovations in the UK protected through plant variety protection over the period 1965-2000.

2. Renewal Model

Plant variety protection certificates are seldom marketed or traded and hence their private value is usually not observed. Using the model developed by Schankerman and Pakes (1986), we will attempt to infer the value of plant variety rights from the economic responses of PVP certificate holders. In almost all countries with PVP legislation, certificate holders must pay an annual renewal fee in order to keep the certificate in force. If it is assumed that certificate holders make their renewal decisions based on the value of returns they obtain from the renewal, then the data on renewal of PVP certificates and renewal fee schedules contains information on the *private* value of PVP rights[2]. Such a renewal model implies that protected plant varieties for which protection is more valuable (e.g. because it commands a larger market share) will be protected by payment of renewal fees for longer periods of time. A breeder will not renew protection for a variety for which he sees no commercial potential. The estimates of the private value of PVP certificates derived from renewal models can be used to supplement the data on the *number* of PVP certificates as a measure of inventive output. It is also possible to estimate how the average value of PVP certificates differs across crop groups or over time. If the distribution of the value of PVP certificates is highly skewed and dispersed, then the number of certificates granted alone may not be a good indicator of the value of breeders' innovations.

Following the assumptions of the Schankerman and Pakes (1986), it is assumed that each cohort of PVP certificates is endowed with a distribution of initial returns, which decay deterministically thereafter. The model allows both the distribution of initial returns and the decay rate to vary over time. It is assumed that certificate holders choose the lifespan of the certificates so as to maximise the discounted value of net returns (i.e. current returns minus renewal fees). Schankerman and Pakes show that for a given schedule of renewal fees, these assumptions imply a sequence of renewal proportions over age for each cohort. The proportion of PVP certificates renewed in each year depends on parameters, which determine the distribution of initial returns and the decay rates. Their model estimates a vector of parameters, which makes the renewal proportion predicted by the model as close as possible to the ones actually observed.

Let us consider the case of a plant breeder who holds a PVP certificate. Let j denote the cohort year of the PVP certificate and t its age so that t + j represents the year (in which renewal decisions are made). In order to keep the certificate in force, the breeder has to pay an annual renewal fee, which generally varies with the age of the certificate. Renewal fees are periodically revised, and once revised, apply to all renewals irrespective of the cohort of the certificate. Let the sequence of renewal fees (in real terms and taking into account periodic revisions) at different ages be denoted by $\{C_{tj}\}$. A breeder who pays the renewal fee earns the return to protection in the following year, which can be denoted by R_{tj}. It is assumed that R_{tj} is known with certainty at the time the PVP certificate is granted. The breeder has to maximise the net value of discounted returns by choosing the optimal age at which to stop paying the renewal fee.

Given an assumed functional form for the distribution of initial returns, the model derives the relationship between the predicted renewal proportions and the vector of parameters of the distribution of initial returns and the decay rates. The functional form, which was found to best fit the sequence of the renewal propor-

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[2] Renewal models by their very nature can estimate only the private value of PVP certificates, which *can* be appropriated by the IPR holder. As Schankerman and Pakes (1986, p. 1069) observe: "It should be emphasised that these estimates refer only to the *private* value of patent rights. We cannot address the broader question of social benefits of patent protection with the present model of renewal behaviour. The social benefits must encompass both the private value and gains in consumer surplus created by the additional R&D effort which is stimulated by patent protection (these latter gains, of course, continue after the patent has expired)". The self-reproducing nature of seed implies that breeders have considerable difficulty in appropriating returns from their innovations. The renewal model used in this paper also estimates only the private returns that can be appropriated by the plant breeder or the certificate holder.

tions, was the lognormal distribution[3]. If R_{0j} (initial returns) follows a log-normal distribution, then:

$Ln\,R_{0j} = r_{0j} \sim N(\mu_j, \sigma^2)$ where N(.) denotes the Normal distribution

Using a lognormal functional form for the distribution of initial returns, the model yields the following estimation equation[4]:

$$y_{tj} = \phi^{-1}(1 - P_{tj}) = \frac{-\mu_j}{\sigma_j} + \frac{c_{tj}}{\sigma_{tj}} + \frac{\sum_{\tau=1}^{t} Ln\,d_{\tau j}}{\sigma_j}$$

where $d_{\tau j} = 1 - \delta_{\tau j}$ and $\delta_{\tau j}$ is the decay rate of initial revenues of cohort j in each time period.

P_{tj} = Proportion of certificates of cohort j renewed at time t.

Schankerman and Pakes (1986) allow for inter-cohort differences in the distribution of initial returns, by allowing cohort-specific variation of μ, but maintaining a common value of σ. This is equivalent to letting cohorts of PVP certificates differ by a proportional rescaling of the initial returns of all certificates in a given cohort. They also allow decay rates to vary across decades. Thus, if the renewal data span three decades (decade1, decade 2 and decade 3) then:

$$y_{tj} = \frac{\left(-\mu_j + c_{tj} - t_j\,Ln(1-\delta)\right)}{\sigma} - \left(\frac{\beta_1}{\sigma}\right)\sum_{\tau=1}^{t} D_{tj}^1 - \left(\frac{\beta_2}{\sigma}\right)\sum_{\tau=1}^{t} D_{tj}^2$$

where it is assumed that:

$$d_{tj} = (1 - \delta_{tj}) = (1 - \delta)\exp\left\{\beta_1 D_{tj}^1 + \beta_2 D_{tj}^2\right\}$$

and D_{tj}^1 and D_{tj}^2 are dummy variables such that:

$$D_{tj}^1 = \{= 1 \text{ if } t + j \text{ (renewal year) falls in decade 2 and}$$
$$\{= 0 \text{ otherwise}$$

and

$$D_{tj}^2 = \{= 1 \text{ if } t + j \text{ (renewal year) falls in decade 3 and}$$
$$\{= 0 \text{ otherwise}$$

Positive values of β_1 and β_2 indicate a decline in the rate of decay during decade 2 and decade 3 relative to decade 1.

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[3] The other distributions that have been commonly used in patent renewal models are the Weibull and Pareto-Levy distributions.

[4] For a derivation of the estimating equation please see Schankerman and Pakes (1986).

The estimation of the value of PVP certificates was based on the above equation. The equation was estimated using non-linear least squares. One modification made in estimating the value of PVP certificates was that instead of allowing cohort-specific values of μ, the value of μ was allowed to vary only across three time periods in order to reduce the number of parameters to be estimated.

3. Description of Data

The estimation of the private value of PVP certificates was attempted for agricultural and ornamental crops in the UK over the period 1965-2000[5]. The UK has been a pioneer in the provision of IPRs for plant variety innovations. With legislation enacted in 1964, the UK has four decades of experience in the implementation of plant variety protection. Among EU countries, it has been one of the leading issuers of PVP certificates. Thus, the data for the UK are able to provide fairly large cohort sizes for agricultural and ornamental crops. There are two important reasons why we have not included the post-2000 grants in the dataset used for estimation of the model. The first is that from the year 2006, the UK stopped levying renewal fees for PVP certificates. This implied that after 2006, PVP certificate holders would have no incentives to surrender their certificates before the full term (unless they are not able to "maintain" the variety for other reasons) based on a comparison of renewal costs and returns. The second reason is that given the average length of survival of wheat varieties from 5-7 years, the inclusion of grants over the period 2000 to 2006 would have led to a large increase in the proportion of censored observations in the dataset which would have significantly increased the standard errors of the estimates of the duration model.

A key element of this study was assembling a comprehensive dataset on plant variety protection certificates issued in the UK since inception of PVP legislation to 2000. This dataset was put together from the information contained in various issues of the *Plant Varieties and Seeds Gazette* published by DEFRA[6] over this 36 year period. The dataset covers all species/genera of plants that have been protected in the UK and contains 13,365 records (including both grants and unsuccessful applications). Using this database it was possible to derive for each cohort the proportion of PVP certificates renewed at different ages.

There are three important components of the total cost of obtaining a PVP certificate. These are (a) application fee (b) examination fee for DUS[7] testing and (3) annual renewal fee for keeping the certificate in force. While the application fee is a one-time fee, the examination fee has to be paid for each year or growing season over which the variety is tested and the renewal fee has to be paid each year. Data was provided by DEFRA on PVP application, testing and renewal fee schedules for the period 1964-2000. Data on renewal fees is essential for the application of renewal models to PVP certificates. It must be noted that PVP fee schedules are periodically revised. When a schedule is revised, the revised fees apply to all PVP certificates renewed after the revision, irrespective of the cohort to which they belong.

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[5] Data was collected for agricultural, horticultural and ornamental crops. However, estimation of the private values of horticultural crops could not be undertaken because the cohort sizes were too small.

[6] Department of Environment, Food and Rural Affairs in the UK and its predecessors.

[7] Distinctness, Uniformity and Stability.

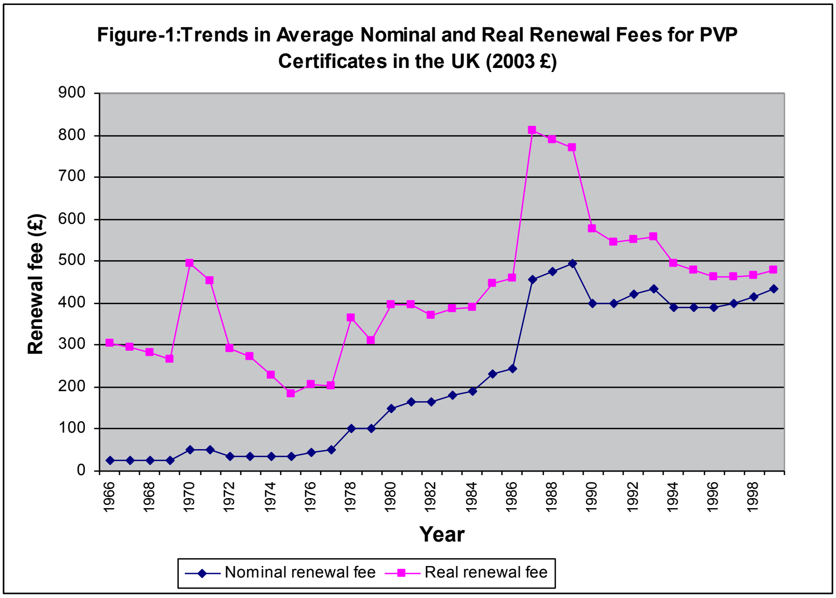
The fees applicable in nominal terms were converted into real terms (2003 = 100) using a GDP deflator. Certain key features of PVP costs that emerge from the data are as follows:

a. Application fees, examination fees and renewal fees are in general higher for agricultural crops than they are for horticultural and ornamental crops. Cereals tend to have the highest costs and ornamentals the lowest. The costs are set at a relatively high level for cereals probably because cereal varieties are expected to have a higher volume and total value of sales in relation to other crop-groups. At the same time, the fee schedule itself can influence the number of varieties offered for protection. PVP grants in the UK (and most other countries) are dominated by grants for ornamental species. One factor responsible for this may be the relatively low PVP fees that are set for ornamentals, which allows varieties with limited commercial potential also to be offered for protection.
b. Application and examination fees constitute only 25-35% of the total discounted cost of obtaining a PVP certificate and keeping it in force for a period of 20 years or the statutory maximum period. For a variety for which protection remains in force for the full term, renewal fees constitute a major portion of the cost.
c. Unlike some other EU countries, renewal costs in the UK do not increase with age. In absolute terms, the renewal fees are fairly modest. For the year 2000 cohort, the annual renewal fee was on average £ 435 for agricultural varieties, £ 320 for horticultural varieties and £ 175 for ornamental varieties. The discounted costs of obtaining a PVP certificate for a cereal variety and keeping it in force for 20 years are under £ 10,000. In spite of the modest levels of PVP fees, a large number of PVP certificates do get surrendered before their full term. This suggests that there may be a large concentration of PVP certificates very with little private economic value.
d. Renewal fees in nominal terms have increased significantly since mid-sixties, but in real terms these costs have remained remarkably stable (Figure-1). Renewal fees have in fact declined in real terms after a spurt in the mid-1990s. Over the entire period, renewal fees for cereal varieties in real terms have only increased from £ 300 to about £ 470 per annum (in 2003 prices).
e. Since 1995, breeders in the UK have had the option of obtaining EU-wide protection through the Community Plant Variety Office[8] (CPVO) instead of obtaining national protection. Initially the expectation was that the cost of obtaining and maintaining EU-wide protection through the CPVO would be higher than the cost of obtaining national protection in individual countries, but would still provide considerable savings in transaction costs to the breeder in relation to the cost of securing national protection separately in several countries. However, at present while application and examination fees for EU-wide protection are higher than those for national protection, the renewal costs set by the CPVO are lower than those set by several EU

[8] The Community Plant Variety Office issues PVP certificates valid in all the countries of the EU against a single application made by the breeder. This substantially reduces the transaction cost faced by the breeder for obtaining protection in several countries. The system of EU-wide grants has not replaced national PVP grants. It is still possible for a breeder to apply for protection in individual EU countries under the relevant national PVP law. A breeder's decision on whether to seek protection separately in one or more countries or to seek EU-wide protection will depend on the commercial potential of the new variety. EU-wide protection cannot be held simultaneously with national protection – if EU-wide protection for a variety is obtained through the CPVO, then national protection has to be surrendered. The grants made by the CPVO are not reported as national grants.

countries for national protection. For instance, the annual renewal cost for a wheat variety protected in the UK is £ 475 whereas it is only 200 euros in the CPVO. This may encourage breeders in the UK to give up national level rights to secure EU-wide rights. This may also account for the decline PVP applications in the UK over the last 5 years for certain genera/species. It is likely that in the EU, in the course of time, national level protection will remain relevant only for those varieties, which have no potential market outside a country.

Figure 1. Trends in Average Nominal and Real Renewal Fees for PVP Certificates in the UK (2003 £)



The data used for the analysis is described in Table 1 and Table 2.

Table 1. Data for survival analysis by Crop Group (Cohort range 1965-2000)

Crop Group	Total number of PVP certificates	Number of expired/ surrendered/ terminated certificates	Number of valid certificates as at 31/12/2000 (censored cases)	Percent censored
Agricultural	2313	1794	519	22.44
Horticultural	1262	983	279	22.11
Ornamental	3556	2584	972	27.33
Overall	7131	5361	1770	24.82

Table 2. Mean and median survival durations

Crop group	Mean survival duration (years)	Median survival duration (years)
Agricultural crops	6	4
Horticultural crops	9	5
Ornamental crops	8	5

Test Statistics for Equality of Survival Distributions of Different Crop Groups

Test	Statistic	df	Significance
Log Rank	154.42	2	.0000
Breslow	112.22	2	.0000
Tarone-Ware	128.02	2	.0000

As in most other countries with PVP legislation, PVP grants are dominated by ornamental crops. Grants for ornamentals account for 50% of all grants, while agricultural crops (which include cereals) account for only 32%. The remaining 18% is accounted for by grants for horticultural crops (mainly fruit species). The proportions are similar when we consider the currently valid grants. It is somewhat surprising that an IPR instrument which is primarily intended to encourage innovation in agricultural crops (food crops and industrial crops) has its greatest impact on the generation of ornamental varieties. As discussed later, this may be partially explained by the differences in the appropriability regime for agricultural and ornamental crops.

Figure 2. Kaplan-Meier Product Limit Estimates of Survival Function of PVP Certificates of Different Crop Groups

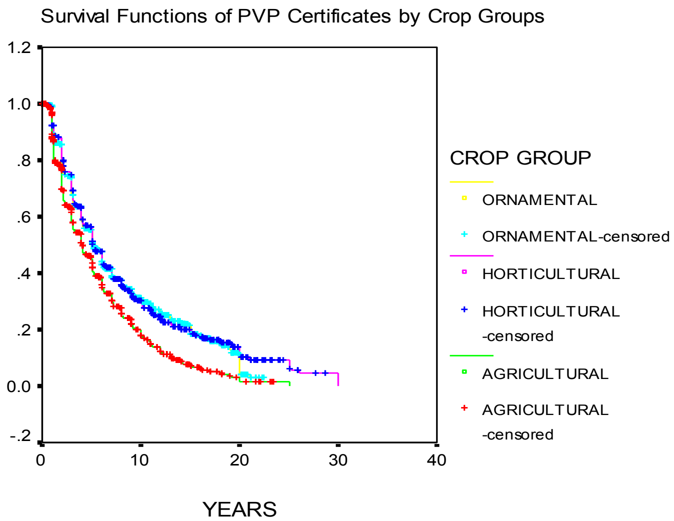


Table 3. Data for survival analysis by crop group and time periods

Crop Group	Total number of PVP certificates	Number of expired/ surrendered/ terminated certificates	Number of valid certificates as at 31/12/2000 (censored cases)	Percent censored
Cohort time period 1965-80	1683	1648	35	2.08
Agricultural	439	433	6	1.37
Horticultural	416	396	20	4.81
Ornamental	828	819	9	1.09
Cohort time period 1980-90	2399	1944	455	18.97
Agricultural	782	710	72	9.21
Horticultural	468	359	109	23.29
Ornamental	1149	875	274	23.85
Cohort time period 1990-2000	3049	1769	1280	41.98
Agricultural	1092	651	441	40.38
Horticultural	378	228	150	39.68
Ornamental	1579	890	689	43.64
Total for all crop groups and cohort time periods	7131	5361	1770	24.82

There are statistically significant differences in the survival patterns of varieties in different crop groups (Table 2). Ornamental and horticultural varieties survive for significantly longer durations than agricultural varieties. The Kaplan-Meier survival functions for PVP certificates of the three crop groups for all cohorts from 1965-2000 are plotted in Figure 2. The survival function for ornamentals completely dominates the survival function for agricultural varieties – that is, at any age the proportion of ornamentals surviving is greater than agricultural varieties. For all crop groups, the mean/median survival duration of PVP certificates is considerably less than the maximum duration of protection allowed under the legislation of 20-25 years. Only 40 to 60% of PVP certificates for agricultural crops survive for more than five years and less than 30% survive for more than ten years. Less than 3% of the certificates survive for the full term. The average agricultural variety survives remains protected for only for 6 years. The fact that on average IPR royalties are collected by breeders over a relatively short time span has important implications for the appropriability of returns from variety innovations.

There are significant differences in the survival pattern of varieties within crop groups across decades. For the purpose of analysis we have divided the entire period into three time periods 1965-1980, 1980-1990 and 1990-2000. The data for these three time periods is summarised in Tables 3 and 4 and the Kaplan-Meier survival functions are plotted separately for each time period in Figure 3. The mean and median period of survival of varieties within crop groups has steadily fallen from the 1960s to the 1990s. This shows that the turnover of varieties quickened over the three decades. The declining mean period of survival in the context of an increase in the number of PVP grants indicates that new varieties have been faced with increasing competition over time. The relative patterns of survival have remained the same, with the survival function for ornamental varieties dominating that of agricultural varieties in all the three time periods.

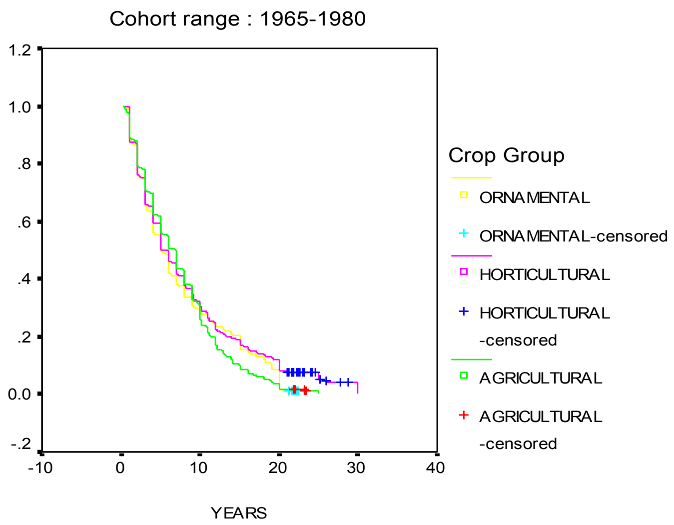
Table 4. Mean and median survival durations

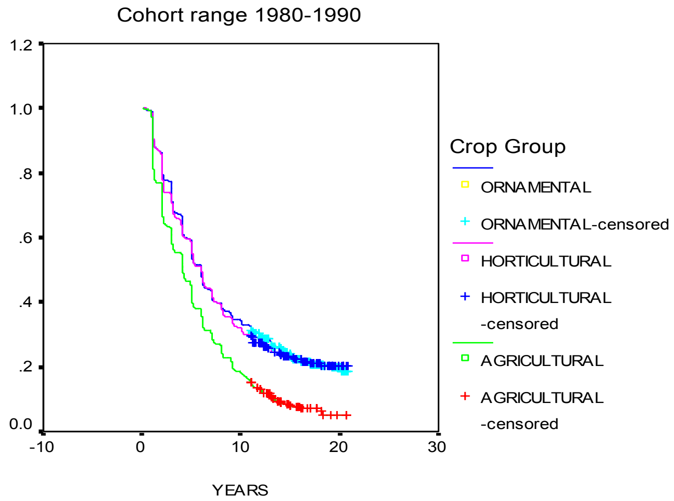
Crop group	Mean survival duration (years)			Median survival duration (years)		
Cohort time period	1965-80	1980-90	1990-2000	1965-80	1980-90	1990-2000
Agricultural crops	7	6	4	7	4	3
Horticultural crops	8	9	6	6	6	4
Ornamental crops	8	9	6	5	6	6

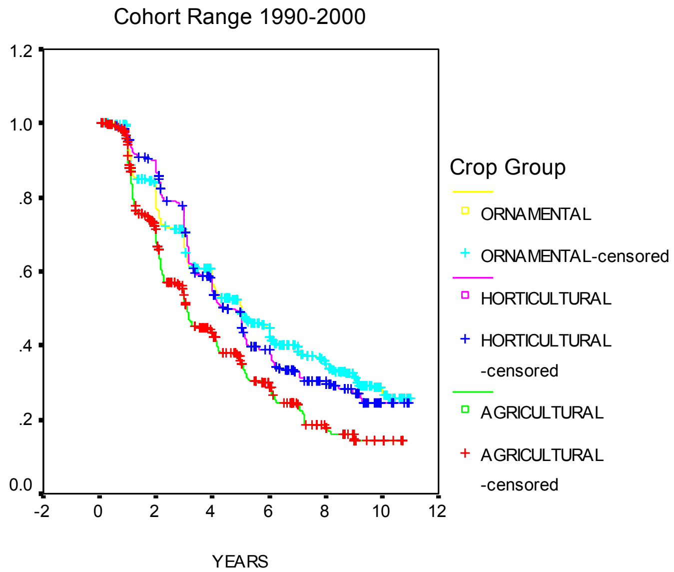
Test Statistics for Equality of Survival Distributions of Different Crop Groups

Test	Statistic	df	Significance
Log Rank	154.42	2	.0000
Breslow	112.22	2	.0000
Tarone-Ware	128.02	2	.0000

Figure 3. Kaplan-Meier Product Limit Estimates of Survival Function of PVP Certificates of Different Crop Groups by Time Periods







4. Estimation of the Renewal Model

The results of the estimation of the renewal model for agricultural crops are presented in Table 5. The results of three sets of regressions are presented. Regression (1) presents the results of a model, which allows for no cohort-specific variation in the distribution of initial revenues ($\mu_j = \mu$ for all j). Regression (2) allows μ_j to vary across time periods. That is, μ_1 represents the value of μ in the period 1965-1979, μ_2 the value in the period 1980-1989 and μ_3 the value in the period 1990-2000. Regression (3) allows μ to vary as in regression (2) but in addition allows variation in the decay rates across the three time periods.

Table 5. Regression Results of Renewal Models for PVP Certificates-Agricultural Crops*

	Model		
Parameters	(1)	(2)	(3)
μ	7.95 (0.80)	-	-
μ_1	-	7.70 (0.38)	7.66 (0.44)
μ_2	-	6.93 (0.25)	6.90 (0.27)
μ_3	-	6.60 (0.21)	6.61 (0..20)
σ	3.05 (1.02)	1.97 (0.35)	1.93 (0.14)
δ	0.36 (0.10)	0.26 (0.04)	0.26 (0.052)
β_1	-	-	$0.0107^{\$}$ (0.0165)
β_2	-	-	$-0.0001^{\$}$ (0.0208)
δ_1**	-	-	0.25
δ_2**	-	-	0.26
R^2	0.78	0.85	0.857
df	333	331	329

Note:
μ_1 = Relates to 1965-1979
μ_2 = Relates to 1980-1989
μ_3 = Relates to 1990-2000

β_1= Relates to 1980-1989
β_2= Relates to 1990-2000

* Figures in parentheses are standard errors.
**$\delta_1 = 1-(1-\delta)*\exp(\beta_1)$ and $\delta_2 = 1-(1-\delta)*\exp(\beta_2)$
$ Not significant at 5% or 10% level of significance.

4.1 Agricultural crops

The key parameters of the model μ, σ and δ all have the right signs and are statistically significant[9]. The high values of R^2 indicate that the lognormal distribution fits the

[9] The only parameters not significant at the 5% level of significance are the parameters β_1 and β_2 which allow the decay rates to vary across the three time periods (regression (3)).

data reasonably well[10]. An F-test clearly rejects the hypothesis that all the μs are equal, that is, there is no inter-cohort variation in the distribution of initial returns. The mean value of the distribution of initial returns from a cohort of varieties is given by $e^{\mu + 0.5\sigma^2}$ in a lognormal distribution. Taking figures from regression (3), we find that the mean value of initial returns of PVP certificates in the UK has steadily declined over the three time periods from £ 13,663 during 1965-1979 to £ 6,389 1980-1989 to £ 4,781 1990-2000. The decline in mean values has taken place alongside an increase in the *number* of PVP certificates issued (except in the post-1995 period when the number of certificates issued annually has not increased – possibly owing to the increasing use of EU-wide protection by breeders)[11]. For any given sequence of decay rates, a decline in the mean value of the distribution of initial returns implies that the present value of returns from the average protected variety has declined. If returns to titleholders accrue in the form of royalties linked to the volume of seed sales over the life[12] of a variety, then it can be seen that the present value of returns depends on the sequence of market shares obtained by the variety. A decline in the mean value of initial returns then suggests that the (cumulative) market share obtained by the average protected variety has declined. This may be due to competition from a larger number of varieties and/or an accelerated turnover of varieties in the post-PVP period. In this paper we have not examined the relationship between PVP and the introduction of new varieties. But in general, in most European countries, the post-PVP period has seen a proliferation of varieties along with a much quicker turnover of varieties. The declining mean value of initial returns, however, does not preclude the possibility of a few varieties in the tail of the distribution acquiring very large market shares.

The degree of skewness in the distribution of initial returns is illustrated by the ratio of the mean to the median value. For the log-normal distribution this is given by $e^{0.5\sigma^2}$. This ratio is 6.4 for the UK. The distribution of initial returns is, thus, skewed to the right and rather sharply so. The estimated rate of decay (regression(2)) is 26%, which suggests that PVP certificates tend to lose value fairly rapidly. When we allow decay rates to vary, we find that decay rate declined in 1980-1989 compared to 1965-1979 but (marginally) increased in 1990-2000 relative to 1965-1980. However, it must be noted that the co-efficients β_1 and β_2 which produce these effects are not significant. An increase in the decay rate could be expected as the result of the changes associated with the introduction of the EU-wide system of protection through the CPVO. After the CPVO was established in 1995, breeders had an incentive to switch from national protection to EU-wide protection through the CPVO, provided their varieties had market potential in several EU countries. But for acquiring EU-wide rights, national rights have to be surrendered or kept

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[10] R^2 is computed as 1 -(Residual sum of squares/Corrected total sum of squares). In the case of non-linear regression R^2 is not bound by 0 and 1.

[11] In our analysis, we have grouped together all agricultural crops. Consequently, the mean value of the distribution of initial returns has not been separately estimated for different agricultural crops. It must be noted that the potential market share of a variety does depend on crop. In the case of crops where varieties are adapted for being grown over large areas ("widely-adapted varieties"), the potential market share of a variety may be larger compared to a protected variety in a crop where varieties are locally oriented. However, the potential market share of a new variety depends not only on the general adaptability of varieties in a crop, but also on the degree of competition from competing varieties. The potentially larger market share of widely adapted varieties could be offset by competition from a larger number of varieties.

[12] The reference here is to the "protected" life of a variety, or the duration for which a variety remains protected.

suspended. This may lead to a jump in the decay rates reflecting only the upsurge in the "surrender" of certificates at the national level owing to breeders switching to EU-wide protection. However, the impact of such switching is not reflected in the data.

4.2 Ornamental crops

Table 6. Regression Results of Renewal Models for PVP Certificates-Ornamental Crops*

	Model		
Parameters	(1)	(2)	(3)
μ	7.92 (0.79)	-	-
μ_1	-	8.15 (0.97)	8.21 (1.06)
μ_2	-	8.49 (1.12)	8.40 (1.12)
μ_3	-	7.93 (0.95)	7.98 (0.95)
σ	2.48 (1.03)	2.30 (1.32)	2.05 (1.34)
δ	0.32 (0.082)	0.35 (0.100)	0.38 (0.11)
β_1	-	-	0.098$ (0.052)
β_2	-	-	0.019$ (0.0416)
δ_1**	-	-	0.325
δ_2**	-	-	0.377
R^2	0.75	0.756	0.763
df	375	373	371

Note: μ_1 = Relates to 1965-1979
μ_2 = Relates to 1980-1989
μ_3 = Relates to 1990-2000

β_1= Relates to 1980-1989
β_2= Relates to 1990-2000

* Figures in parentheses are standard errors.
**$\delta_1 = 1-(1-\delta)*\exp(\beta_1)$ and $\delta_2 = 1-(1-\delta)*\exp(\beta_2)$
A very small positive value
$ Not significant at 5% or 10% level of significance.

The results of the renewal model for ornamental crops are presented in Table 6. The three sets of regressions are the same as that for agricultural crops. The results for ornamental crops are a very similar to those for agricultural crops. Again, the key parameters of the model μ, σ and δ all have the right signs and are statistically significant (though β_1 and β_2 are not significant in regression (3)) The mean value of the distribution of initial returns increased from £ 30,069 in 1965-1979 to £ 36,360 in 1980-1989 before declining to £ 23,890 in 1990-2000. The interesting feature of these results is that the mean values of ornamental varieties are 2-3 times the mean values for agricultural varieties. There has been a steady upward growth in the number of certificates in the UK, especially in the late 1980s and till the mid-1990s. Therefore, as in the case of agricultural crops, the number of new varieties or innovations produced every year has increased over time, but the value of the *average* innovation has decreased. The number of new varieties protected and the mean value of initial returns appear to have moved in opposite directions. This again may be the result of a larger number of varieties competing for market share.

The distribution of initial returns is skewed to the right in the case of ornamentals as well with a mean to median ratio of 8.17. The decay rate of 32% (regression (2)) for ornamentals is higher than that for agricultural varieties, suggesting that ornamental varieties lose value faster. When we allow for variation in decay rates (regression (3)), we find that the decay rate increases marginally to 32.5% in 1980-89 and to 37.7% in 1990-2000. It must be noted, however, that the co-efficients β_1 and β_2 are not significant at the 5% level of significance. If β_1 and β_2 are not significantly different from zero then the decay rate has not changed over the decades.

5. Private value of PVP Certificates

The parameters of the renewal model estimated for agricultural crops and ornamentals can be used to derive the private value of PVP certificates i.e. the net returns that are appropriated by the titleholder. The present value of a single PVP certificate denoted by V is given by:

$$V = \sum_{t=1}^{T} \frac{R_t - C_t}{(1+i)^t} = \sum_{t=1}^{T} \frac{[R_0\,(1-\delta)) - C_t\,]}{(1+i)^t}$$

where R_t - C_t is the net return from holding a PVP certificate during age t, i is the discount rate, δ is the decay rate and T is the optimal life span of the PVP certificate based on the renewal rule discussed earlier (i.e. the certificate will be renewed only if $R_t > C_t$). The assumption of a lognormal distribution for the initial returns (R_0) for a cohort of certificates leads to a distribution of V. The estimates of the parameters μ, σ and δ are used to generate the distribution of V by simulation. To do this, 50,000 random variables were drawn from a lognormal distribution with the estimated values of μ and σ and V was calculated for each one of them using the decay rate, the renewal fees applicable in any given year and the renewal rule. From this derived distribution of V, the quantiles of the private value of PVP certificates could be derived. Tables 6 and 7 present for agricultural crops and ornamentals respectively the distribution of the private value of PVP certificates for three different cohorts in constant 2003 pounds.

The key feature of the value distribution for both agricultural crops and ornamental crops is the sharp skewness. There is a high concentration of PVP certificates with

Table 7. Estimates of the private value distribution of PVP certificates for agricultural crops in the UK (all values in constant 2003 UK £)

	1975 cohort	1985 cohort	1990 cohort
Estimated parameters of the renewal model			
μ	7.66	6.90	6.61
σ	1.93	1.93	1.93
δ	0.2649	0.2569	0.2650
Value distribution			
Mean	24,436	11,525	7,911
Minimum	0	0	0
Maximum	3,829,475	1,705,080	1,337,739
Percentile 25	380	0.30	0
Percentile 50	2,762	856	275
Percentile 75	13,735	5740	3,777
Percentile 95	96,609	46,390	32,447
Percentile 99	376,988	182,444	130,363

μ = Mean of the distribution of initial returns from PVP certificates on agricultural crop varieties
σ = Standard deviation of the distribution of initial returns
δ = Decay rate of initial returns
Note: Value distribution estimated by simulation

very limited private economic value[13]. For agricultural crops, the median value of a PVP certificate was £ 2,762 for the 1975 cohort, £ 856 for the 1985 cohort and only £ 275 for the 1990 cohort. There is a sharp rise in the value of PVP certificates in the third quantile, but most of the value of PVP certificates is concentrated in the tail of the distribution, especially in the top 1%. For agricultural crops only 1% of the protected varieties were worth more than £ 130,000 for cohorts in the 1990s. Similarly, for ornamentals, the median value of a PVP certificate was £ 3,598 for the 1975 cohort, £ 5,768 for the 1985 cohort and £ 2,782 for the 1990 cohort. The top 1% of the certificates had a private

[13] The assumption of a constant and deterministic decay rate, which implies that the returns (R_t) obtained by a breeder tend to monotonically decline over time, tends to bias the estimated private value of PVP certificates downward. Indeed, here we measure the minimum private returns to holders of PVP certificates in the circumstances. In the case of plant variety protection, returns to the titleholder generally accrue in the form of royalties linked to the volume of seed sales over the life of the protected variety. The royalties obtained by the titleholder are likely to be related to the rate of producer adoption, i.e., it will depend on the sequence of market shares obtained by the variety. A typical new variety may take some years to reach peak market share, after which market share may decline. The sequence of market shares generally follows an inverted-U pattern. The sequence of returns obtained by the titleholder may also follow a similar pattern. The assumption of a constant decay rate may be more appropriate to industrial process inventions where the licensing income obtained by a patent holder may decline over time as competing innovations become available. The incorporation of the adoption and diffusion pattern of protected varieties in the renewal model may significantly increase the mean value of the distribution of the private value of PVP certificates. While we have not attempted to do so in this paper because of the difficulties that it poses in estimation, it can be seen from Tables 7 and 8 that even a significant increase in the private value distribution is unlikely to affect our conclusion that that private economic value of the bulk of PVP certificates is very modest.

Table 8. Estimates of the private value distribution of PVP certificates for ornamental crops in the UK (all values in constant 2003 UK £)

	1975 cohort	1985 cohort	1990 cohort
Estimated parameters of the renewal model			
μ	8.21	8.4	7.98
σ	2.05	2.05	2.05
δ	0.3893	0.3250	0.3374
Value distribution			
Mean	33,808	52,274	27,896
Minimum	0	0	0
Maximum	6,280,324	9,664,581	5,213,735
Percentile 25	566	883	287
Percentile 50	3,598	5,768	2,782
Percentile 75	17,325	26,916	14,086
Percentile 95	127,955	197,593	106,039
Percentile 99	376,988	182,444	130,363

μ = Mean of the distribution of initial returns from PVP certificates on ornamental varieties
σ = Standard deviation of the distribution of initial returns
δ = Decay rate of initial returns
Note: Value distribution estimated by simulation

value in excess of £ 445,000. The inescapable conclusion is that the bulk of PVP certificates generate only very limited privately appropriable returns[14]. The highly skewed distribution of private value of PVP rights is consistent with the results of studies of the values of patent rights for industrial products[15].

Interestingly, the mean value of private returns appropriated from ornamental varieties is 1.5-3 times that appropriated from agricultural crop varieties. This has interesting implications for the proportion of the market value of seed appropriated by PVP titleholders in the case of agricultural and ornamental crops. For an accurate assessment of this proportion, we need to estimate the private value of a cohort of PVP certificates and the market value of the seed sold of varieties included in the cohort *over the life of the varieties*. The private value of a cohort of PVP certificates can be estimated by multiplying the mean value of the cohort (from Tables 6 and 7) with the number of certificates issued in that year. In the UK, in 1990, a total number of 389 grants were made, of which 161 related to agricultural crops and 198 to ornamental

[14] It must be clarified that the private value of PVP certificates estimated by the renewal model reflects the returns attributable to the holding of IPRs alone. The results only suggest that the 'pure' private returns to holding IPRs (and that too in the form of PVP and not patents) are modest. To generate returns from a new variety, IPRs have to be combined with other complementary assets such as production, marketing and distribution capabilities. The factors, which affect the distribution of returns between the innovator and the owners of the complementary assets, are discussed later.

[15] Based on an extensive survey of UK industry, Taylor and Silberston (1973) concluded that only a very limited number of patents generate substantial licensing income for the patent holders. Schankerman and Pakes (1986) too found that the bulk of patents in UK, France and Germany had very little economic value.

crops (the remaining 50 related to horticultural crops). The private value of the 1990 cohort of protected agricultural varieties was thus £ 1.273 million, while the 1990 cohort of ornamental varieties was valued at £ 5.5 million (current prices). We do not have the estimated value of the seed sales of varieties included in the 1990 cohort over the life of the varieties. However, it may be seen that the private value of the 1990 cohort of agricultural varieties constituted just 0.04% of the value of agricultural crop output of £ 3,088 million in that year, while the private value of the cohort of ornamental varieties constituted 1.08% of ornamental crop output of £ 506.4 million[16]. Thus, the private value of a cohort of ornamental PVP certificates constitutes a much larger proportion of the value of output than a cohort of agricultural crop certificates. As the seed market value is generally related directly to the value of the crop[17], these figures suggest that titleholders for ornamental varieties appropriate a larger proportion of the seed market value than titleholders of agricultural crop varieties. The absence of farmers' exemption (plant-back rights) in the case of ornamentals and the ease of detecting IPR infringements are probably the factors that increase the appropriability of returns from protected varieties of ornamentals. Better appropriability of returns in the case of ornamentals may also explain the large number of grants for ornamentals in most countries[18]. At the same time, the loss of revenue to breeders on account of farmers' exemption may be an important reason explaining the lower proportion of seed market value appropriated by breeders of agricultural crop varieties[19].

The low average value of PVP certificates may appear to be somewhat surprising, especially against the background of large profits made by multinational seed companies. However, low average private values of IPR holdings and the highly skewed distribution of private value are not unusual in the literature and are not unique to PVP certificates. A large number of studies on the private value of patent rights (a much stronger form of IPR protection) for different sectors of the economy have found very similar results. (Schankerman and Pakes, 1986; Pakes, 1986; Schankerman, 1998; Sullivan, 1994). It must also be noted that inventors and plant breeders can and do use various methods to protect their innovations, including IPRs (patents or PVP certificates), trade secrets, different forms of first mover advantage etc. (Levin *et al.*, 1987; Cohen, Nelson and Walsh, 1996). The decision to seek IPR protection for an invention or a new plant variety depends on the costs and benefits of these alternative benefits. For example, in the case of hybrids, trade secrets based protection of parental lines may provide adequate protection for a new variety. The private value of IPRs represents only the *incremental* returns that could be generated by holding IPRs, above and beyond what could be earned using the alternative means (Schankerman, 1998). The private value of PVP certificates, therefore, does not constitute the entire value of the returns to innovation in plant breeding.

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[16] The figures for the value of agricultural and ornamental crop output are from OECD (2000). The value of agricultural and ornamental output, of course, includes the output of varieties not included in the cohort. The comparison is, therefore, intended only to illustrate the difference in appropriability between agricultural and ornamental crops.

[17] The seed market value is estimated at less than 10% of the value of crop output in the case of agricultural crops (OECD, 2000). For ornamental crops, it is estimated to be between 10-15% of the value of output.

[18] In most countries with PVP legislation, grants for ornamentals account for 50-80% of all grants made.

[19] Over the last decade, plant back rights for farmers have been circumscribed in the EU. Only "small farmers" are allowed the privilege of using the saved seed of protected varieties without payment of royalties to the titleholders. Our calculation relates to 1989 when payment of royalties on saved seed of protected varieties was not a widespread practice.

In order to assess the relative importance of patent protection, relative to other methods of appropriating returns from invention, the "equivalent subsidy rate" (ESR) is often used. It is the ratio of the total value of patent rights to the R&D used to produce those patents. It is an approximation to the cash subsidy that would have to be paid to R&D performers to yield the same level of R&D if patent protection were eliminated. Schankerman (1998) finds that the ESR for patents ranges from 15-24% and these estimates are very similar to those found in a number of other studies on patent renewal models. An ESR of 25% indicates that patent protection generates as much as a quarter of the total private returns to R&D. But the finding also implies that 75% of the private returns to R&D must come from sources other than patents. This finding is consistent with survey evidence that finds that firms rely on many methods to appropriate rents from inventions (Levin *et al.*, 1987) and that the importance of patent protection varies greatly across industries (Taylor and Silberston, 1973).

We do not have the data necessary for the estimating the ESR in the case of PVP certificates. While the estimated private value of a given cohort of certificates can be obtained as described earlier, we do not have the R&D cost of producing the cohort because these costs may be spread over the years leading to the development and protection of new varieties. However, for a rough comparison it is possible to compare the private value of the 1990 cohort of PVP certificates with the aggregate national agricultural R&D expenditures for that year. This comparison is shown in Table 9. Such a comparison, no doubt, ignores the fact there is always a lag between R&D expenditure and PVP output. It also ignores the fact that not all the private value of PVP certificates in a country accrues to nationals, while research institutions and companies may also receive the value of varieties protected abroad. Moreover, the aggregate agricultural R&D expenditures do not relate to plant breeding alone. Nevertheless, the comparison does show that the private value of a cohort of PVP certificates constitutes a small fraction (2%) of the annual agricultural R&D expenditures. In the literature on the evaluation of returns from agricultural research, estimates of rates of return of 30% and above are quite common (see, for instance, the survey by Alston *et al.*, 1998)[20]. The implication is that the private value of PVP certificates appropriated by the titleholders constitutes a relatively small portion of the overall returns from agricultural R&D.

The low private values of PVP certificates also reflect the fact that IPRs by themselves do not ensure the capture of value (Teece, 1987; Rausser, Scotchmer and Simon, 1999). In order for the innovator to appropriate returns from his/her innovations, IPRs have to be combined with a range of complementary assets[21]. In the case of innovations in plant breeding, the key complementary asset is a marketing and distribution network that can reach the innovation to farmers. Our concern here is with the distribution of privately appropriable returns from an innovation between the innovator, imitators and the owners

[20] These estimates relate to the total social returns from R&D and not to private returns alone. These studies also vary considerably in the elements of agricultural research expenditure that they include in the analysis.

[21] Complementary assets are assets with which the innovation must be combined in order to make the innovation useful and valuable to the consumer. Teece (1987) distinguishes between three types of complementary assets. "Generic assets" are general purpose assets that do not need to be tailored to the innovation in question. "Specialised assets" are those with unilateral dependence between the innovation and the complementary asset. "Co-specialised assets" are those with bilateral dependence.

Table 9. Private Value of PVP Certificates and Agricultural R&D Expenditure

	Agricultural crops	Ornamental crops	Horticultural crops
Number of PVP grants made in 1990	161	198	50
Estimated mean discounted private value of PVP grants of 1990 cohorta	7911	27,896	27,896
Total estimated value of the whole cohort of 1989 (= mean value x number of grants)	£1.273 m	£5.5 m.	£1.395
R&D expenditure on agriculture by business enterprises		£98.25 m	
Public sector agricultural R&D expenditure		£290.80 m	
Total agricultural R&D expenditureb		£389.05 m	
Private value of PVP rights as a percentage of total agricultural R&D expenditure		8.168/389.05 =2%	

Note: (a) As we do not have the mean value estimates of grants for crops which are not agricultural or ornamental crops, we have taken the mean value of agricultural crops (Table 7) or the mean value of ornamental crops (Table 8), whichever is higher, and multiplied it by the total number of grants for all crops. Choosing the higher of the two values implies that the estimated discounted private value of the cohort is biased upward. However, this only reinforces the conclusion that the private value of PVP certificates constitutes a small portion of the returns from agricultural R&D; (b) The figures of agricultural R&D expenditures shown in the table do not relate to plant breeding. alone. However, it should be noted that the figures exclude R&D expenditures on 'agro-chemicals' and 'food and beverages'.
Sources: (i) OECD Basic Science and Technology Statistics 1999 (R&D Expenditure by business enterprises on 'Agriculture, Fisheries and Forestry'). (ii) OECD Basic Science and Technology Statistics 1999 (Government budgetary outlays on R&D for the socio-economic objective 'Agriculture'). R&D expenditure/outlay figures in current prices have been adjusted to 2003 base using a GDP deflator.

of complementary assets (seed producers and distributors)[22]. The key determinants of this distribution are (1) the regime of appropriability and (2) market structure in the ownership of complementary assets.

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[22] It must also be noted that IPRs and the relevant complementary assets can be brought together in myriad ways. These range from contractual modes (e.g., arms-length licensing by an innovator with independent suppliers or distributors) to "integrated" modes (e.g., where the innovator and the owners of complementary assets merge). In general, contracting rather than integrating, is likely to be the optimal strategy when the innovator's appropriability regime is a strong one and the complementary assets are in competitive supply (that is, there is adequate capacity and a choice of sources). In the seed industry, contractual modes are rare – there are few instances of independent plant breeders licensing their varieties to large seed firms; invariably, the plant breeding operation is also owned by the seed production and distribution firm. The predominance of the integrated mode suggests that the appropriability regime for innovators is weak and the complementary assets may not be in competitive supply.

The regime of appropriability refers to environmental factors, excluding firm and market structure that govern an innovator's ability to capture profits generated by an innovation. The appropriability regime depends on (a) the efficacy of the legal system to assign and protect intellectual property (scope and breadth of IPRs, efficacy to enforcement etc.) and (2) the nature of technology – whether the protected innovation is a product or a process, whether the knowledge embedded in the innovation is codified or tacit (these characteristics affect the ease of imitation). In the case of new plant varieties, both these factors make for a weak appropriability regime. Plant varieties are self-reproducing and lend themselves easily to imitation and modification. Besides, PVP law generally allows for researchers' exemption and farmers' privilege that reduce the flow of rents to the certificate holders. Enforcement of PVP rights is also rendered difficult because the consumers (farmers) are large in number and widely dispersed. Teece (1987) also notes "access to complementary assets, such as manufacturing and distribution, on competitive terms, is critical if the innovator is to avoid handing over the lion's share of profits to imitators and/or to the owners of complementary assets that are specialised or co-specialised to the innovation" (p. 197).

There is considerable evidence of market power in seed production and distribution[23]. At the global level the top ten seed companies account for approximately 40% of the commercial seed market valued at US $ 15 billion (RAFI: 1997). The four-firm concentration ration (CR-4) is approximately 21%. The world seed market is relatively fragmented compared to the agro-chemical industry where the top ten firms account for 82% of global sales. But concentration at the national level is high in most developed countries and in some developing countries. Given the location-specificity of plant varieties and the limited movement of protected varieties across countries, national levels of concentration may be more relevant in assessing market power. In the United States in 1980, the four largest corn seed firms accounted for 57% of the market. By 1997, the CR-4 ratio had risen to 69% (Goldsmith, 2001). With the recent extensive merger and acquisition activity, the DuPont-Pioneer and the Monsanto-Dekalb-Holden complexes now influence nearly 90% of the corn market (Hayenga, 1998). The soyabean market is less concentrated as Pioneer and Monsanto have only 19% of the market share each. The CR-4 ratio is 47%. The cotton seed market is the most concentrated. At one stage (when the takeover of Delta and Pineland Co. by Monsanto was in the offing) it appeared that Monsanto alone would have 84% share with the CR-4 ratio above 90%.

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[23] The market power exercised by seed companies is not attributable entirely to variety ownership. This can be seen most clearly in the case of private seed companies in developing countries that operate in the absence of an IPR regime. In many developing countries, which have opened up the seeds sector to private and/or foreign investment, private companies have acquired significant market shares in several crops within a relatively short span of time (Morris: 1998). It is true that the private seed industry in developing countries has tended to focus on hybrids (which have an inbuilt technological protection). But it is important to note that many of the varieties sold by private companies are publicly-bred hybrids with no IPR protection. While hybrids protect a firm against replication of seed by farmers, they do not provide any protection against imitation (as the varieties are themselves in the public domain). A large part of private sector activity in developing countries has also been based on the multiplication and distribution of self/open pollinated public sector varieties, which are again not protected by any form of IPRs and are easy to replicate. For instance, in India, it is estimated that nearly 50% of commercial seed in wheat (a self-pollinated crop) is now supplied by private firms, which continue to thrive even in the absence of any IPR-based barriers to entry. The profits of these companies cannot be attributed to variety ownership (as the varieties are in the public domain) but must be seen as returns to the complementary assets discussed above.

Therefore, a weak appropriability regime and the existence of market power in the ownership of complementary assets may mean that the incremental return appropriated by the innovator on account of IPRs are low. In the above discussion we have treated the innovator and seed producer as separate entities. But even when the innovator and the seed producer constitute a single entity, it is conceptually possible to distinguish between the returns that accrue on account of IPR ownership and the returns that accrue to the ownership of complementary assets. The renewal model is able to infer the incremental private value accruing to the innovator on account of owning a PVP certificate. The fact that even PVP certificates owned by large companies are seldom held for the full term (when annual renewal costs are only in hundreds of pounds) is an indication that a marginal calculus is being applied – that is, incremental returns from PVP are being compared with the renewal costs.

The weakness of PVP as an IPR measure has certain other implications as well. If plant breeders have stronger alternative modes of protecting their varieties, they will switch to them and the use of PVP is likely to decline. This trend is most sharply visible in the U.S.[24] where the number of PVP certificates issued every year has declined from about 300-400 to about 60-70 in the late 1990s, while the number of utility patents issued for plant varieties has steadily increased. This trend is not yet very apparent in European countries possibly because of the legal uncertainties surrounding the patentability of plant varieties[25]. As alternative modes of protection become available, the switch away from PVP can be expected in other countries as well. Thus, while developing countries currently in the process of enacting PVP legislation are worried about the monopoly profits that plant breeders may reap, in developed countries the use of PVP is likely to decline because it facilitates only limited appropriability. The increasing importance of biotechnology based innovations in agriculture may accelerate this trend as such innovations appear to call for stronger forms of protection. It is noteworthy that genetically modified varieties of agricultural crops are being protected by utility patents (and not through plant variety protection) in countries like the US, Japan and Australia where such protection is available.

6. Conclusion

In this paper we have used a renewal model to estimate the distribution of private value of PVP grants. The most striking feature of the value distribution of PVP grants is

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[24] It must be noted that US PVP law is considerably weaker than it is in EU countries. The US law explicitly allows plant-back rights to farmers, i.e., farmers can use the seeds obtained from the harvest of a protected variety for re-sowing their own land. In the EU farmers have to pay a royalty to the breeder or titleholder even when they use the seeds obtained from the harvest of a protected variety, though an exception is made for the category of small farmers. In the US, "farmers' privilege" has been considerably circumscribed by judicial decisions, and farmers are no longer allowed to sell up to 50% of the seed obtained from the harvest of protected variety as "unbranded" seed ("brown bagging" is no longer permitted). It is also important to note that if a variety is protected by patents (rather than by a PVP certificate), then farmers' privilege and researchers' exemption do not apply.

[25] The European Patent Convention does not allow plant varieties to be protected. However, the position may change as the result of the European Union's "Directive on the Protection of Biotechnology Inventions (Directive 94/44EC) which contains specific provisions on the patentability of genetically engineered biological material including plants and animals. However, there are still a number of unresolved issues (see Eratt *et al.*: 2000).

their sharp skewness, which indicates that there is a large concentration of PVP rights with very little private economic value. PVP emerges as a relatively weak IPR measure, which allows the private appropriation of only a small fraction of the total returns from an innovation. In developed countries, there are already signs that PVP is being replaced by stronger forms of IPRs as the instrument of choice for protection.

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