Assessing the economic implications of different models for implementing the requirement to protect plant varieties

Review of the Economic Literature on Plant Breeders' Rights

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As the author of the report, the views and ideas expressed here are my personal and reasoned views; no other person or institutions bears any responsibility for its contents. Comments are welcome and can be directed at the address below.

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1 Introduction

Attention on issues concerning introducing IPRs in plant genetic resources in the Global South was largely prompted by the Uruguay Round negotiations where in an early negotiating draft plant varieties were included within the ambit IPRs. Thus, in the early 1990s, a variety of commentators agreed that either there was “little evidence” (Lesser 1991) or “mixed and inconclusive evidence” (UNEP 1996) of the benefits of introducing IPRs in plant varieties in the Global South. Reflecting a cautious approach, something earlier expressed that the tradeoffs in the South are remarkably different (Barton 1982), commentators have consistently recommended a detailed policy analysis before introducing PBR (Godden 1984). Ironically, despite the lapse of over a decade, this has been emphasised now in the context of TRIPs implementation (IPGRI 1999; Rangnekar 2002a). Only a few countries from the South offered any form of intellectual property protection for plant genetic material prior to the coming into force of the TRIPs Agreement. Evidence of this review exists in very few some countries in the South (see for India, Wood and Bombin 1990). The literature reviewed here is remarkable for its very limited theoretical sophistication and/or sound methodology (Godden 1987; Kennedy and Godden 1993; Rangnekar 2000). This is verdict is a reflection of the limited transference of models and methodology developed in the economic literature dealing with patents. For instance, in the case of patents, economists have developed models that attempt to capture various aspects of patents, like the trade-off between length and breadth of protection (Nordhaus 1967; Scherer 1972; Klemperer 1990) or the ‘racing’ and ‘waiting’ games played by competing patentees (Dasgupta 1988). Evolutionary economists have also schematised the relationship between patent scope and the mode of technical advance (Merges and Nelson 1990) and the conceptualised the multiple appropriation strategies across sectors of technology (Levin, Klevorick et al. 1987; Klevorick, Levin et al. 1995). This sophistication and broad analytical approach has yet to be adequately incorporated into the specific study of PBRs or the general study of IPRs in the area of plant genetic resources. As a consequence, the literature that is reviewed here tends to be mainly of an empirical nature. A few studies are comprehensive and comparative in that they cover a number of activities of the plant breeding and seed industry and also provide a comparison of a selection of country case-studies (van Wijk and Jaffe 1996; International Union for the Protection of New Varieties of Plants (UPOV) 2005;

Louwaars 2005)

2 Theme One – R&D and Investment

2.1 *Theoretical issues*

A central premise underlying the introduction of IPRs is the inappropriability of knowledge (Nelson 1959; Arrow 1962). While Nelson (ibid.) does note that firms with economies of scale might overcome this problem, it is more popularly accepted that some levels of inappropriability prevail. Inappropriability is associated with the public good characteristics, of knowledge is on account of the following: uncertainty in predicting the returns, non-excludability (of benefits) and non-rivalry (in consumption). Owners of information are unable to maintain their monopoly position on information as any purchaser can simply reproduce it at little (or no) cost (Arrow, 1962). Thus, to the extent that property rights are difficult to establish and enforce there will be an under-investment in investments in research (Dasgupta and David 1994). These appropriability problems are compounded, it has been argued, in the case of plant breeding by features of the technology and the product (Lim 1993; Rangnekar 2000). Technical change is embodied and the artefact – the seed – can not only be recycled and re-used; but it also can be easily diffused because it can be *multiplied*. No doubt, some contributors to the literature also notes the multiple appropriation strategies that seek to resolve and overcome this problem of appropriability. Reflected of a limited theoretical sophistication, the literature on PBRs has inadequately theorised this appropriability problem. For example, it has not acknowledged the inherent duality in the ‘market for seeds’ that a breeder faces (Godden 1982). Not only does a breeder confront competing breeders who might ‘pirate’ the variety but also, what Godden (1982) terms, “second and less obvious” farmers who may retain seed from the harvest. Maybe to Godden’s surprise the latter has been the main focus of the inappropriability problem. A useful way forward is to understand the hardware/software duality in ‘seeds’ that refers to the seed production – plant breeding division in industry (Lewontin and Berlan 1990).

The introduction of IPRs is directed at alleviating this appropriability problem; hence much research has been focussed on the relationship between and impact of IPRs on R&D. Promoting private investments in research remains a primary policy rationale for IPRs. In the case of patents, as noted elsewhere in the review, economists have developed sophisticated models that assess this incentive effect (see for example, Reinganum 1981; Bound, Cummins et al. 1984; Griliches 1990; Schankerman and Lanjouw 1998). These models and the accompanying empirical contributions (see in particular, Mansfield, Schwartz et al. 1981; Mansfield 1984; Mansfield 1986).

Little of these theoretical preoccupations have filtered into the research on PBRs (and by extension on the general research on plant breeding R&D). In particular, empirical work focuses on the 'impact' of IPRs in terms of a 'before' and 'after' approach; thereby suggesting that evidence identified is causally linked to the event (introduction of IPRs). There are few exceptions and the review draws attention to them.

2.2 *Empirical evidence*

Capturing changes in the breeding effort can be reflected in a number of different empirical indicators, such as (a) number of firms with plant breeding programmes, (b) R&D expenditure per firm per dollar of sales, (c) number of plant breeders employed by the private sector – and obviously in 'output' indicators like the trend rate of plant varieties released. This remains reminiscent of a linear 'pipe-line' model of the innovation process (Brooks 1994). With respect to the trend rate of plant varieties released, interest is not in a mere increase in the number of varieties released but also in their productivity and other agronomic features. Further, beyond documenting these indicators, it would be useful to explore how representative these trends are. That is, which companies, what crops, what type of breeding and how these trends are situated in a historical sense? For empirical studies, this remains problematic. For example, a well cited study of PBRs in the US acknowledge that there is no way to assess how representative their sample size might be (Perrin, Kunnings et al. 1983, p24).

Studies that focus on the US come with some of the following shared observations (Perrin, Kunnings et al. 1983; Butler and Marion 1985; Butler 1995; Frey 2000; Alston and Venner 2002): while private sector investments in plant breeding increased following the passage of the PVPA in 1970, the impact was moderate in size, selective in terms of crops (i.e. wheat and soybean) and not equitably spread out amongst firms. For example, studies with rich survey-based data (for example, Perrin, Kunnings et al. 1983; Butler and Marion 1985) reveal that increases in investments are not evenly spread across all firms, with a tendency for older firms demonstrating higher initial trends.

A relevant observation in some of the studies relates to the 'role' of PBRs. Some studies have explored the stimulating impact of PBR (Kloppenburg 1988) and the politics of inclusion/exclusion of crops from the ambit of the law (Kloppenburg 1988; Bugos and Kevles 1992; Fowler 1994). Reviewing the evidence, Rangnekar (2002) identifies a variety of factors that stimulated demand for soybean; thus investment in breeding. These factors include (a) historical trend of increasing acreage under soybean cultivation, (b) fragility of the soybean seed, which disallows farm-seed saving, (c) expanding downstream food processing industry based on soybean, and (d) increasing international trade in soybean. The case of increases in private investment in wheat breeding (in the US) can has also been evaluated. Alston and Venner (2002) note that between 1970 and 1993, private sector investments remained static and increases where on account of public sector investments. Surveying investments in financial and human resources to plant breeding in the US in 1994, it has been difficult to establish a link to the changes to the PVPA (Frey 1996). Increased investments in wheat breeding activity can be explained by the concentrated focus on developing hybrids (Knudson and Ruttan 1988).

Evidence in other countries is not as detailed and rich and has tended to focus on the 'output' side – the trends in release of new plant varieties. A general, or rather popular, claim in the literature is that "the availability of PBRs has increased the number of private sector breeders, as well as the number of varieties released and planted" (Lesser 1990, p60). The claim is (partially) supported by evidence reviewed above and well-known critics accept that the number of varieties released have increased after introduction of PBRs; though noting the occurrence of cosmetic breeding (Mooney 1983, pp150-54). For that matter, evidence for the US indicates that the number of varieties released in the 1990s is higher than that in the 1980s (Fuglie, Ballenger et al. 1996, p36). A study on PBRs in Canada reported selective increased breeding activity and release of new varieties (Canada Food Inspection Agency 2001). Increased breeding activity was reported in horticultural crops whereas static activity was noted in most other crops (esp. grains and oilseed). A study of the impact of PBRs in Spain found a positive incentive effect on private breeding activity that saw international firms enter the Spanish market (Diez 2002). However, as foreign breeders focus on hybrids the 'incentive' role of PBRs remains doubtful.

A methodological question remains in terms of whether the availability of protection *caused* the increase in the indicator used as a proxy for the breeding effort. For instance, in the case of using the number of plant varieties, this would require an examination of changes in the trend rates of release of new varieties before and after the 'event' – the introduction of PBRs. To begin, this would help discern if historical changes and assist in shedding some insight into questions of causality: 'do innovations *cause* the increase in PBRs or is it the other way around?' Naturally, this examination will need to identify and disaggregate other factors that influence the breeding activity and rate of introduction of new plant varieties. An effort at analysing historical rates of varietal release for select UK crops across 1930-90 that uses the enacted of the *Plant Varieties and Seeds Act, 1964* as the 'event' provides mixed evidence: an increase for apple; a marginal change for French beans and negligible influence for strawberry (da Rocha 1994). Beyond this econometric exercise, da Rocha (1994) notes that species wise difference in the impact of PBRs is primarily explained by biological factors and economics, such as the timing and cost of breeding, the life-cycle and turnover of the crops, and the natural barriers for propagation. Similar reflections exist in a study of vegetables and fruit plant breeding in the US where focus is on the juvenile period of the species and the exclusion costs to stall 'piracy' (Stallman 1986).

There are few studies that have analysed trends in the pattern of investments. Venner (1997) analysed the trends in both public and private investments in wheat breeding in the US up to 1994, more than 20 years after the introduction of the U.S. PVPA. While private expenditures remained relatively static, public expenditures on wheat breeding actually more than doubled in real terms. Venner also found that the premium of wheat seed price over the wheat commodity price, 'an upper-bound estimate of the royalty rate', decreased in real terms over the period 1954-1994, thus providing no evidence of an increase in appropriability of research expenditures in wheat breeding. It would be difficult to associate the increase in public investments to the existence of IPRs. In the case of wheat, much of the increase has been accounted for by the search for hybrids in wheat (Knudson and Ruttan 1988). Across all crops, Alston & Venner (2003) funds private investment remaining relatively static. These nominal changes in private investment do not appear to be associated with PVPA (Frey 1996).

Studies on the 'incentive' effect of PBRs in the global south are difficult to find. Apart from the three key studies noted earlier (cf. section 1), there is a diverse literature on 'seed system' development (see in particular, Jaffee and Srivastava 1992; Jaffee and Srivastava 1994). Some commentators adopt this framework and have sought to hypothesise trends to follow the introduction of PBRs (Pray, Ramaswami et al. 2001). This literature is useful and provides pertinent insights into the role of seed market regulations. Changes in the seed market regulations can provide the necessary impetus for the entry of private seed firms and investments in plant breeding (Tripp and Rohrbach 2001). Evidence of this exists also in India, for example in the market for rice seeds in Andhra Pradesh (Tripp and Pal 2001).

The three based studies that focus on countries in the Global South are empirical and do not adopt any particular theoretical approach. Observations include a focus on the (annual) number of plant varieties introduced and the specie-distribution of the same. In terms of R&D there is some sketchy data on the level of investment. However, there are observable emergent trends in terms of the social-economic division of labour between the private sector and the public sector. For example, in Argentina, MNCs predominantly focus on hybrid crops and the public sector (and domestic breeding companies) almost entirely focuses on open-pollinated varieties (van Wijk and Jaffe 1996). Having secured the inclusion of inbred parental line within Argentina's PBR legislation, the number of protected inbreds increased to 112 in two years (ibid.). Louwaars et al. (2005) report, with varying intensity of detail, the number of applications and grants for the countries included in their study. However, there is no attempt to discern changes in the rate of introduction of new varieties; hence leaving open the question of the 'incentive impact' of PBRs and causality.

The study conducted by UPOV presents the most detailed data amongst the three studies. It adopts a rather simplistic methodology of comparing the number of varieties released and/or protected around prior to and after two key events: the enacted of PBRs legislation and accession to UPOV[1]. By way of example, in Argentina in the 'pre-PBR' period (1982-91) there were 26 varieties and the 'post-PBR' period (1992-2001) there were 70 varieties. The particular event that marks the borders of the two periods is the passage of the PBRs legislation. This is methodologically flawed. To begin, the study fails to reflect on the rate of introduction of plant varieties in a historical sense. More importantly, to establish proof of a causal relationship that can be reduced to a

[1] The section on China, however, does not have this 'pre' and 'post' PBR legislation data work.

single event (or regulatory change) requires a robust empirical test of the relationship where other interfacing influences need to be identified and their impact isolated.

It appears that most would agree that there is a moderate and/or weak incentive effect of PBRs on R&D. For some, the weak effect is principally on account of the relatively feeble protection offered by PBRs in comparison to patents (Alston & Venner, 2002). In this respect, it is pointed out that, in comparison to patents, the scope of protection is narrow, the exceptions, particularly for farmers, are too broad, and that there is no principle of utility. There may be some empirical truth to this argument as it is observed that breeders have tended to favour the patent route (Naseem et al., 2005). This observation tends to gloss over two key elements to the argument. First, the jurisdictional element in that a choice between different IP instruments only exists in a few jurisdictions. Second, the conditions for grant of protection differ between the two. This would suggest that in other settings a claim for dismissing the incentive effect of PBRs may not be as feasible. Studies in the Global South of the 1980s make an important point in this respect. Reflective of the policy concern of the 1980s, i.e. widening the use/adoption of ‘improved’ seeds, many researchers commented that capacity for distributing these seeds was the limiting factor. To some extent, it was also the case that the private sector did not expand their operations. Yet, it was found that “the absence of PBRs is not seen as a problem, neither by the agricultural seed companies nor by horticultural seed companies. They do not see any problem in the absence of adequate legislation either” (Wierema 1989, p10).

Economists have contrasting views on the underlying presumption that stronger protection necessarily results in increased inventive activity. This relationship, though, has been examined in statistical terms. Kanwar & Evenson (2003) found significant correlation between an index of IPR strength and economy-wide expenditures on R&D. Pardey et al. (2003) adopting a similar methodology studied the case of the plant breeding industry and found a positive correlation between the index and number of PBR applications for 42 countries (1997-2001). A study of a selected sample of 13 countries, find a positive correlation between IPR strength and PBR certificates granted (Srinivasan 2002). Interestingly, while there is a positive correlation with the number of certificates granted to foreigners, the share granted to foreigners is negatively correlated to IPR strength and market size. There is strong causal presumption here in establishing that the strength of IPRs are positively correlated with indicators of GDP and/or inventive activity. In particular, it implies that the optimal level of protection is an increasing function of levels of income and complexities of technology (Maskus 2000, pp100-05). In contrast, other economists find a non-linear relationship between the strength of protection and indicators of economic development that holds for comparisons between countries and for countries across time (Maskus and Penubarti 1995). In essence, at very low levels of development and technological capacity, countries tend to have strong IP legislation; consequently, IP legislation is weakened as the economy develops and finally, with increasing economic development, IP legislation is strengthened. A key lesson from this econometric exercise is the endogeniety of the strength of IP laws.

It is difficult to provide any generalised conclusion from these studies. More importantly, it is difficult to extend these conclusions to the specific situation in the countries being studied in the project. There are too many variables that matter and that local, country specific differences compound the specificity that is being encountered at the crop level.

3 Theme Two – Market Consolidation

3.1 *Theoretical issues*

IPRs are inherently associated with some first-order loss of social welfare, much of which originates in the creation of monopoly power through the grant of protection. There are various contingencies on the extent of monopoly power created and the consequent loss of social welfare. For instance, the degree of competitiveness in the market and the elasticity of substitution of the product are factors that influence the ability of IP-holders in exercising their monopoly power. Society provides the monopoly powers in exchange for the technological benefits with the presumption being that some technological benefits cannot be realised without the incentive created by the monopoly powers. If monopoly powers vested in seed companies allow them to restrict competition or entry into the market, then they will be able to earn monopoly rents. Thus, redistributing incomes to breeders at the expense of farmers or consumers and constitute. It is here that various exceptions to the breeders' rights, public interest provisions in law, and wider regulations (e.g. competition policy) come to bear on the potential adverse consequences of IPRs. This is an issue of both efficiency and equity.

David Godden in his various writings on PBRs has suggested that a close proximate market structure for plant breeding is oligopoly[2]. Systematic analysis of empirical evidence corroborates that PBRs are associated with a reduction in the number of active firms. The move towards an oligopoly structure is further entrenched by the peculiarities of the technology paradigm (Rangnekar 2000). In particular, the cumulative, science-intensive nature of plant breeding (and R&D, in general) and the economies of scale that accrue lead towards this configuration. Further, as Godden notes, the advantages accruing to incumbent firms are enhanced by seed market legislations (e.g. National Listing, etc.). These raise the barriers to enter the product market; thus, compounding the hurdles associated with PBRs. As noted later in this section, the tendency towards an oligopoly market structure proceeds alongside the dynamics of integration. Thus, the historical waves of integration between seed/breeding firms and firms in closely allied industries, such as chemicals, food processing, etc.

In terms of the thematic of 'market consolidation', the issue of an oligopoly market structure raises concern because firms have the ability to influence the price of their commodity in contrast to a competitive market where firms are 'price takers'. Further, firms in an oligopoly market tend to pursue a variety of non-price competition strategies. Thus, Godden (1987) reports of firms flooding the regulatory system (and hence, the market) with varieties as a way to out-pace competitors. Quite similar is the evidence of fruit breeders pursuing strategies of multi-product portfolios as a way to constantly maintain a range of varieties on the market (Stallman, 1986). Evidence from wheat breeding in the UK, provides a strong case for identifying breeding strategies directed at planned obsolescence (Rangnekar 2002b). To explain, beyond proliferating the market with varieties, seed companies pursue a dual breeding strategy of incremental productivity improvements and narrow/limited disease resistance. The breeding strategies underpin the rapid turnover rates of varieties, i.e. shortening their durable life spans, which in the case of UK wheat lead to a fall from 13 years (1960s) to 5.5 years (1990s). Other commentators recognise a wider set of non-price methods of appropriation that, flowing from the oligopoly market structure, entrench market consolidation by raising barriers to entry (Goss 1996). Yet, some argue that "[W]hether

[2] See Godden (1982, 1987); Kennedy & Godden (1993).

PVP [i.e. PBRs] results in increased concentration of seed sales depends upon the extent to which seed companies are able to develop superior varieties and effective marketing programmes" (Butler & Marion, 1985, p45)." They recognise that PBR acts like a barrier-to-entry by making a variety private property. However, they suggest caution by emphasising that what is important is the level of concentration and not the mere fact that concentration has increased.

This caution aside, concerns on market consolidation in the seed sector has been constantly expressed and reflects a broad range of views. A rather standard concern about increasing market consolidation, in particular within an oligopoly setting, is that the rate of technical progress and the R&D effort might be compromised. Increasing consolidation, much in contrast to popular perceptions, is strongly associated with diminishing research intensities (Griliches 1984) and has been documented in the context of plant breeding as well (Fernandez-Cornejo and Schimmelpfennig 2004). From an evolutionary economics perspective, it is also argued that the pace of technological progress is swifter in markets that tend to be more competitive (Merges and Nelson 1990). Other commentators have been raising concern about the growing consolidation in the plant breeding sector and similar trends in associated sectors that supply agriculture. An early statement on this drew attention to the acquisition of seed companies in the first wave of consolidation in the 1970s (Mooney 1983). Mooney (ibid.) drew attention to the control that such companies exercise on our diet and also on the narrowing of the food pyramid because of the drive towards uniformity: "For those of us who confine our hunting and gathering to the super grocery stores that now stretch from Kansas to Kuala Lumpur, the neon cornucopia seems endless in diversity" (p7). The alliance between agrichemical firms and seed firms, which constituted a key wave of consolidation in the industry, was equally predicated on acquiring control, primarily through patents, on key technologies (Bijman 2001). The race to patent has seen the filing and granting of very broad patents, e.g. Agracetus's US patent for transgenic cotton in 1992 (no. 5159135), some of which have been challenged and amended/rejected[3].

3.2 *Empirical evidence*

The literature that attempts to unpack and explore these issues face a formidable data hurdle. Collecting and organising data on PBRs is not easy. Apart from getting access to primary data, there is the hurdle of tracing firm ownership across time as the industry proceeds through its different phases of mergers and acquisitions. Not surprisingly, few contributors have attempted this exercise.

Early contributions exploring market consolidation are the studies by Butler and Marion (1985) and Perrin et al. (1983). Time series data is available in Butler and Marion (1985), which indicates the following levels of concentration:

- In marigold, alfalfa and oats the top 2 grant-holders accounted for more than 70% of the grants.
- In pea, bean, lettuce, watermelon, and barley, the top 3 grantees accounted for more than 50% of the grants, whereas in tobacco they held 100% of the grants.
- The top four grant-holders accounted for between 82-91% of the grants in onion, rice, tomato and cauliflower.

These levels of concentration are high, and it is suggested that seed firms that were established well before the passage of the Plant Variety Protection Act have benefited (Butler and Marion, 1985, pp33-38). More importantly, the adverse crop-level distribution of grants corresponds to seed market concentration (Butler and Marion,

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[3] This is the first reported case where one patent covers all transgenic plants of an entire species, i.e., all genetically engineered cotton, regardless of the method used to produce the plants.

1985; Kloppenburg, 1988). Commenting on the US data, some argue that in the long run, competition pressures will eliminate the negative effects of market concentration (Lesser 1991). Yet, recent data (c. 1997) on the North American seed market indicates the contrary (Hayenga 1998):

- Hybrid corn: the top five companies account for 69% of the market, with the market leader, Pioneer Hi-Bred, alone controlling 42%.
- Soybean: the top five companies account for 51% of the market, with the market leaders, Pioneer Hi-Bred and Monsanto, each controlling 19%.
- Cotton seed: the market leader, Monsanto, alone controls 84% of the market, on account of its purchase of Delta and Pine Land.

Time series data for wheat PBRs in the UK has also been documented (Rangnekar, 2000). This demonstrates that the distribution of PBRs in wheat in the UK is highly concentrated and the degree of concentration has increased with time: the top five grant holders accounted for 69% of the grants in 1965-74 which increased to 79% in 1986-95. These high and increasing levels of concentration correspond with concentration in the product market, the market for seeds. The firm with the largest number of grants, Plant Breeding International[4], has consistently controlled 60-80% of the market through the period 1977-95. This, as noted earlier, is the result of a non-price competition through a strategy of planned obsolescence (Rangnekar 2002b).

Unfortunately, there is little else in the literature. It is only in the case of Canola in Canada that some comparable research has been conducted (Carew 2000). Evidence reported is supportive of the theoretical approach presented by Godden (see above), in that an oligopoly market structure prevails with non-price competition strategies. While 10 firms account for most of the plant certificates issued there have been a number of strategic alliances[5]. While the number of varieties remained constant (median 6.5)

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[4] Initially a public sector company, Plant Breeding Institute, it was sold to Unilever in 1987. Later in 1998, Monsanto purchased it from Unilever.

[5] Some of these are between Pioneer and DuPont, Monsanto and Limagrain, Zeneca and Advanta, AgroEvo and Plant Genetic Systems.

between 1982 and 1989, there has been a proliferation of varieties with the number increasing from 12 in 1990 to 57 in 1997. Even as the number of varieties has increased, the share of top companies has remained stable.

Data of the global seed market is notoriously unreliable and difficult to collect. One effort at collating information from company annual reports indicates that, in 1998, US$30bn of the US$50bn global seed market was accounted for by commercial seed sales – of which, 31% was accounted for by the top 23 companies, with the top 3 accounting for 13% (ten Kate and Laird 1999). Another source suggests that the top ten companies account for 30% of global commercial seed sales (Rural Advancement Foundation International 1997).

Many contributors draw attention to different waves in the on-going consolidation of the seed (and now, life science) industry. A first wave of consolidation, in the 1960s/70s, hinged on the acquisition of family-owned seed companies by emergent multinational firms with interests in agricultural chemicals (RAFI, 1998; Thayer, 2001). These mergers and acquisitions were driven by the desire to exploit the latent economies in chemicals by linking into seeds.

The widening scope of application of intellectual property rights in plant material, particularly in the US, is said to have facilitated the second wave of acquisition (Juma 1989, See also Hobbelink, 1990). Thus, in the 1980s, there were acquisitions of biotech start-ups, seed companies and boutique biotech firms. As Falcon & Fowler (2002, p204) comment, it seemed that "virtually all firms were simultaneously trying to buy, sell and sue one another!" The focus on seeds, the delivery mechanism for technical change in agriculture, was succinctly summed up by Teweles (1985, p519)[6]: "… new plant science companies will find it advantageous to participate in the ultimate marketing of science via the seed". In the US, for example, between 1995 and 1998, approximately 68 seed companies were acquired (Pingali and Traxler 2002). This process continued through the 1990s and was marked by the emergence of giant life-science companies like Astra-Zeneca, Aventis, Dow Agrosciences, Du Pont, Monsanto, and Novartis, among others. These companies have a broad portfolio of operation that

[6] Quoted in Goodman et al. (1987).

spans beyond seeds and into agro-chemicals, pharmaceuticals, diagnostics and vaccines.

This stage of the consolidation in the industry is said to have been driven by the need to get access to key technologies and control them through intellectual property rights (Rausser et al., 1999; Graff et al., 2003). In fact, 75% of the Bt patents (in 1999) owned by top five life science companies were obtained following acquisition of smaller companies (CIPR, 2002, p65). A third phase in the post-1999 period has been

Figure 1 Life Science Conglomerates

Major Remaining Companies	MONSANTO [Pharmacia Corporation]	AVENTIS	DUPONT	SEMINIS	DOW CHEMICALS	SYNGENTA (pending FTC approval)	
						NOVARTIS	ASTRAZENECA
Conglomerates		AgrEvo Rhone-Poulenc					
Agricultural Chemical Companies		Hoechst & Schering			Dow Elanco	Ciba-Geigy Sandoz	
Biotech Companies	Agracetus Calgene Ecogen Millenium Pharmaceutical	Plant Genetic Systems PlantTec	Human Genome Sciences Curagen	DNA Plant Technology	Mycogen Ribozyme Pharmaceuticals, Inc.		Mogen Int'l N.V. Japan Tobacco
Seed Companies	DeKalb Asgrow Holden's Foundation Seeds Cargill Int'l Plant Breeding Int'l	Nunherns Vanderhave Plant Genetic Systems Sunseeds Cargill U.S. Limagrain Pioneer Vegetable Genetics	Pioneer Hybrinova	Asgrow Petoseed Royal Sluis Seminis	Mycogen United AgriSeeds	Northrup-King S&G Seeds Hilleshog Ciba Seeds Rogers Seeds Co.	Advanta

Source: Falcon & Fowler (2002)

identified, which hinges on a divestment of agrichemcal interests amongst the largest conglomerates of the life science industry (Falcon and Fowler 2002, see figure 1 above).

In an oligopoly market, firms have the capacity to influence market prices – they are not price takers like firms in a competitive market. Thus, attention is often devoted to the consequence of exercising this market power. Indicators used to explore the exercise of market power are the price of seeds and royalty rates. Again, collecting the relevant data is problematic; hence few contributors have conducted the necessary study. A theoretical conundrum remains in making an assessment of seed price movement and attributing it to the exercise of market power or to other factors. However, first some evidence:

- In the US, expenditures on seeds increased from US$519mn to US$1515 between 1960 and 1980 (constant 1960 dollars) (Perrin et al., 1983). Three-fourths of the increase was on account of seed price rise and the balance on account of increased seed purchases (Butler & Marion, 1985).
- In the US, between 1972 and 1992, real seed prices increased faster than yields (Fuglie et al., 1996, p43).
- In the UK, with the removal of controls on royalty rates, farmers are paying more for seeds (Pray, 1996).

The conundrum of explaining this evidence remains. For some commentators, the focus should not be on the rise of price per se, but on whether the increase is "undue" (Perrin et al., 1983). While this may concede that seed prices will increase, an assessment of the rise will remain a highly subjective decision. In this vein, Perrin et al. (ibid.) suggest that the increase can be explained away in terms of tax and financial activities of the period.

4 Theme Three – Welfare Issues

4.1 *Theoretical issues*

A final set of considerations that relate to IPRs, in general, and PBRs, in particular, concern welfare. This emerges from a variety of perspectives. For instance, while PBR provide incentives for foreign breeders to import and market their products, the question is equally about how the benefits accrue and distribute within the host economy. Thus, it is also about how novel varieties and technologies diffuse within the host economy and the activities of local breeders with respect to access. This issue acquires more importance with the advances in modern biotechnology as these are increasingly being dominated by large agrochemical concerns due to the increased investments necessary and the IPR granted to many of the processes or products involved. The diffusion, or restriction thereof, of improved plant varieties can also be expected to have effects on trade patterns in agricultural crop products.

Following from the theoretical focus on PBRs and oligopoly market structures, the literature also focuses on the welfare impacts of increasing consolidation. Increasing rents that accrue to breeders are at the expense of farmers or consumers and constitute the classic trade-off in the granting of IPR in general. Society provides the monopoly powers in exchange for the technological benefits with the presumption being that some technological benefits cannot be realised without the incentive created by the monopoly powers. If monopoly powers vested in seed companies allow them to restrict competition or entry into the market, then they will be able to earn monopoly rents. Of course, the breeders' exemption is intended to limit this possibility. This issue has been categorised differently by various authors as, for example, 'static allocative efficiency' by (Lesser, 1997), the 'distribution of economic benefits' by (Moschini and Lapan, 1997) or 'appropriation of return from investment' (Srinivasan, 2000). From an economic perspective the issue is the redistribution of welfare benefits (in the static allocative framework of consumers and producers surpluses) accompanying the introduction of new production technology, in the form of improved varieties

4.2 *Empirical evidence*

Little empirical research on the issue of access to technologies (and varieties) and the diffusion (or local adaptation) has been done within the context of PBRs. This may be generally reflective of the wide notion of breeders' exemption that exists in the global IP architecture (i.e. UPOV) and national implementing legislation. Some contributors have documented the 'gentleman's agreement' that exists between competing breeders that delays the use of newly protected varieties for a couple of years (Rangnekar, 2000). Rangnekar also explores the parentage of varieties as means to empirically document the use of the breeders' exemption. However, it is a different matter for the use of protected varieties that have been introduced by foreign breeders. Anecdotal information exists of access to foreign germplasm. For example, an unpublished USAID study of Argentina and Chile, where access to US and New Zealand fruit varieties improved following the introduction of PBRs (Lesser, 1991, p53). It is similarly argued that Monsanto refused access to Bt-cotton in Brazil, despite extensive crop loss from infestation, because of absence of proprietary protection (Lesser, ibid).

Contrasting evidence has also been reported in the literature. A five country study in Latin America concludes that access to germplasm was significantly restricted after the implementation of PBRs (Jaffee and van Wijk, 1995). The transformations that take place are more subtle than apparent. Introduction of PBRs is often followed by dual processes that (a) place pressure on public institutions to behave like 'semiprivate organisations' and (b) motivate closer collaborative research between the public and private sectors. Jaffee and van Wijk (1995: 144) conclude that reduced availability of germplasm was partly because of "joint germplasm improvement programmes" between public and private sectors.

Recent research tends to focus on some of the problems encountered in accessing proprietary agricultural biotechnology technologies in national agricultural research programmes. This is an issue that extends beyond our focus on PBRs; however a brief mention is made. An ISNAR study focused on programmes in Latin America (Cohen et al., 1998; Salazar et al., 2000) and reports the following:

- Dissemination Problems: Extensive use of proprietary technologies exists in international agricultural research centres. While material transfer agreements and licensing of these technologies exist, a sizeable 40% fall within the grey area of 'no user agreement'. While in 37% of the cases no dissemination problems were foreseen, in 14% of the cases clear hurdles to dissemination were placed by the right-holder. In the balance, the situation remained ambiguous.

- Lack of Clarity: 50 distinct end products were identified in the research project and 74% of them were expected to be protected by either patents or PBRs. Lack of clarity on IPRs meant that in about 30% of the cases dissemination may be a problem.

- Multiple Patents: The possibility of multiple patents in either single technologies or in closely related sets of methods of transformation, selected gene markers, traits and gene expression technologies, raise the cost of research whilst also stalling the pace of progress (Lewontin and Santos, 1997; Pardey et al., 2001). The case of 'vitamin A rice' – otherwise known as 'golden rice' (RAFI, 2000) – might be indicative: use of the variety involves clarifying user licenses for over 70 patents (Pardey et al., ibid.).

These recent examples are reflective of the increasing and complicated burden of conducting research in a world dominated by IPRs. In this respect, a particularly given the paradigmatic feature of plant breeding, the exchange of, and access to, genetic material and enabling technologies is highly constrained. Maybe, at times, this is only a potential problem. Yet, it must be recognised that "modern methods used to develop new crop varieties depend on a wide range of component innovations, the rights to which might be held by many competing parties … if ownership is diffuse and uncertain, it can be difficult or impossible for potential users to successfully negotiate with all of the relevant parties" (Pardey et al., 2001). Typical of an earlier era of agricultural research is CIMMYT's wheat variety VEERY (c. 1977), which involved approximately 3,170 crosses using 51 parental lines. It remains to be seen if this is possible in the future.

The issue of welfare and distribution are theoretically more complicated. In the literature there has been no noticeable focus on PBRs. Instead, a growing literature has focussed on the welfare impacts of novel biotechnology products, in particular Bt-cotton, in the Global South (again with a specific focus, China in this case) (see Falck-Zepeda et al., 2000; Pray et al., 2001). The focus of this research is on the distribution of 'benefits' across three groups – breeders, farmers and the rest of society. GM crops, whether in the North or the South, tends to be protected by multiple instruments which include patents (on genes etc.), user agreements, supplier contracts and sales tied to complementary inputs (e.g. agrichemicals).

One approach is to use static welfare analysis to examine the distribution of benefits between farmers, consumers and the seed sector. The traditional framework for evaluating the welfare benefits of technological progress in agriculture (Alston, Norton and Pardey 1995) assumes competitive input markets, including the market for seed. Moschini and Lapan (1997) developed a framework that recognises the monopoly situation created in seed input markets by intellectual property rights over plant varieties in the form of patents. A number of recent studies have applied this framework empirically, focussing particularly on genetically-modified varieties such as Roundup Ready® soybeans, and Bt crops. While not focusing specifically on PBR, the frameworks are relevant for the issue as they could allow an examination of the potential effects of more restrictive forms of PBR on the distribution of benefits. Falck-Zepeda, Traxler and Nelson (2000a) examined the distribution of welfare from the introduction of Bt cotton in the United States in 1996. The study thus estimated the distribution of benefits from the adoption of the technology among US farmers, seed suppliers, US consumers, foreign consumers, and foreign producers. Data was taken from experimental plots as well as a survey of farmers. The analysis modelled the US cotton sector within the framework of a large open-economy with no technology spillovers 1. A large share of the benefits was found to accrue to US farmers (more than half) while the seed providers received about a quarter. US consumers enjoyed rather modest benefits, while foreign consumers benefited somewhat more. Foreign producers were modest losers. - Pray, Ma, Huang and Qiao (2001) have examined the distribution of benefits from the diffusion of Bt cotton in China, referring specifically to resulting from the 1999 crop. The data was based on a survey of farmers and the modelling framework was simplified to allow for simple vertical supply curves 2. The main economic impact of Bt cotton came about as a result of the reduced cost of production (14-33% per kg) as there were not yet any observed effects in the output price markets. Almost all of this benefit (about 80%) was captured therefore by the predominantly smallholder farmer sector as much of the seed planted had been exchanged among farmers under a weak system of IPR 3. This study therefore provides an interesting comparison of how things work out under weaker IPR protection. Although again, the evolution of the legal framework and of markets needs to be borne in mind in interpreting these results. In addition to the benefits enjoyed by smallholder farmers, the study also argues strongly that a major environmental and health benefit of the adoption of Bt cotton in China was the reduced use of pesticide.

Moschini, Lapan and Sobolevsky (1999) applied the Moschini and Lapan framework to the soybean complex to estimate the expected distribution of benefits from the adoption of Roundup Ready soybeans in 1999-2000. Their analysis considered three regions, the US, South America and the rest of the world. In this study, consumers and adopting farm regions benefited while the welfare position of non-adopting regions worsened. The estimated monopolist profits for the seed supplier were sizeable (45% of the global welfare gain). This study also compared the impact of IPR by comparing the simulation of the model with parameter values that could be expected under competitive supply of Roundup Ready soybeans. The estimated efficiency loss from the exercising of market power is extremely small (0.2% of the original net efficiency gains). The authors attribute this to the relatively inelastic supply and demand functions for soybeans 1. But the size of the monopolist benefits is such that were the technology of Roundup Ready soybeans to be competitively supplied, the originating country (the US) would lose considerably while producers in other countries would benefit.

Finally, it is pertinent to note the absence of exploring the impacts of introducing PBRs on the key constituency of farmers. It has been difficult to identify either theoretical or empirical literature that explores this aspect of the issue. No doubt, there are a variety of anecdotal and rhetorical expositions on the loss to farmers and farming communities. In contrast to this concern, there are some contributions that present farm-saved seeds as a disincentive to seed firms. Lesser (1997) reasons that the low pricing margin on protected varieties (discussed above), which is an indication of limited monopoly powers, is because of the 'reduced appropriability' of the exclusive right due to competition from farmer-saved seed. Srinivasan and Thirtle (2000) have proposed a theoretical model to examine the effect of this reduced appropriability on the returns to research. Pray and Basant (1999) report from interviews with major seed firms in India that the inability, even with PBR, to restrict farmer-saving of seed provides a major disincentive to the initiation of major breeding programs for the Indian market. It can also be reasoned that, as a result of this, seed suppliers may seek to capture an even larger margin with seed sales in order to compensate lost benefits due to farm-saved seed in future plantings. Hansen and Knudson (1996) developed a framework for econometrically testing this hypothesis and applied it to the soybean industry in the US. They found statistically significant evidence of indirect appropriation and conclude that farmer-saved seed in the soybean sector does not decrease incentives for varietal development. This implies that farm-saved seed does not provide as much competition for private varieties as might be claimed, at least for soybeans. It is worth noting that this analysis was undertaken before the introduction of Roundup Ready soybeans, a genetically-modified organism (GMO), in the US which would probably offer an interesting opportunity for revisiting the analysis. This area of research is particularly relevant for the policy choices concerning the scope of protection under a sui generis system. As mentioned above, a key consideration is the farmers' privilege, with the UPOV 1991 Act admitting the possibility of greater restrictions on this privilege. The very limited empirical analysis undertaken in the US would suggest that maintaining the farmers' privilege does not impinge on the incentives for R&D and does not even form a serious form of competition. Thus, due to other benefits it provides (e.g. food security), there would be little economic basis for excluding or restricting this exemption from a sui generis system. But the studies need to be undertaken for other crops and in other countries. As Lesser (1997) points out, it is essentially an empirical issue. The interest of some seed developers in the genetic use restriction technologies (GURTs) indicates a concern about competition from farm-saved seed. With this issue, it is possible to contemplate studies in countries that have only introduced IPR for plant varieties more recently, as the longer historical time series of data, while always more robust, is not as necessary as with the R&D studies summarised above

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