



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

**53rd Annual Conference of the Australian Agricultural and Resource
Economics Society, Cairns, North Queensland**

10-13 February, 2009

**Evidence for increasing concentration in plant breeding industries in
the United States and the European Union**

Elizabeth Nolan and Paulo Santos

University of Sydney

Evidence for increasing concentration in plant breeding industries in the United States and the European Union

Preliminary: Do not cite.

Elizabeth Nolan and Paulo Santos^{*#†}

Abstract

There is evidence of an increase in market concentration and in the importance of private plant breeding in the seed industry following the widespread adoption of Intellectual Property Rights regimes for the industry in the developed world. We use data from the US Patent and Trademark Office, US Plant Variety Protection Office and various European Plant Variety Protection databases to estimate the extent of these changes in the seed corn industry.

Key words: Intellectual Property Rights, R&D, market concentration, germplasm

1. Introduction

Intellectual Property Rights (IPRs) regimes for sexually reproduced plants were introduced in the European Union (EU) in the late 1960s and in the United States (US) with the passage of the Plant Variety Protection Act of 1970. The Trade Related Aspects of Intellectual Property (TRIPS) Agreement requires all members of the World Trade Organisation to introduce at least a *sui generis* Plant Breeders Rights (PBR) or Plant Variety Protection (PVP) regime. The experience under the regimes in the US and the EU may provide a guide to what might occur in other countries if a regime were introduced and enforced. In this paper we suggest a possible new proxy for market concentration, which may assist with planned empirical work to explore the link between market structure and innovation.

An important argument for IPRs is that it leads to increased innovation and an increase in available knowledge. However, there is no compelling evidence that this is always the case. There is considerable anecdotal evidence that IPRs for plant breeding, in those countries which have introduced and enforced it, has been associated with an increase in industry concentration and a move from public to private plant breeding, but there is less empirical work. A major concern about

* Contributed paper presented at the 53rd Annual Conference of the Australian Agricultural and Resource Economics Society, Cairns, North Queensland, 10-13 February, 2009.

The authors are, respectively, Associate Lecturer and Associate Professor in the Discipline of Agricultural and Resource Economics, Faculty of Agriculture, Food and Natural Resources, University of Sydney

† The authors would welcome comments on this paper. Corresponding author Liz Nolan at l.nolan@usyd.edu.au

agricultural biotechnology, IPRs and increasing concentration is the control a few large firms, who may not invest in developing new products with the greatest social benefit, may be able to exercise over the global food supply (Harhoff *et al.* 2001; Sheldon 2008). If the more widespread availability of IPRs for plant breeding has had impacts on innovation, welfare or distribution of welfare, or on efficiency it would be useful to be able to quantify these effects. In this paper we focus on corn seed since, unlike cotton, soybeans and canola, it is a staple food in some regions.

Analysis of the effects of IPRs for plant breeding is limited by lack of data. Data relating to market share and R&D expenditure are not readily available, as the information is commercially sensitive. However, information about the ownership of plant varieties is available from patent and plant variety databases. Patent data have been used to measure innovation and concentration in innovation in the agricultural biotechnology sector (see, for example, Harhoff *et al.* 2001; Graff *et al.* 2003; Brennan *et al.* 2005; King and Schimmelpfennig 2005). However, these studies focus on biotechnology crops in general rather than specific crops. Levels of concentration vary between crops. We suggest that the share of ownership of germplasm, as an essential input for modern varieties of corn, could be used as a proxy measure of market concentration in the corn seed market. We use data from the databases of the United States Patent and Trademark Office (USPTO) and the United States Plant Variety Protection Office (PVPO) as well as up-to-date information on company structure, collated from a variety of sources, to determine the share of ownership of germplasm in the US over the period since the introduction of PVP legislation in 1970. We include, for comparison, preliminary data for the European Union (EU) from the databases of the Community Plant Variety Office (CPVO) and the Groupement National Interprofessionnel des Sémences et Plants (GNIS) to demonstrate that the development of the EU breeding industry may not have followed the same path as in the US.

2. Background

Historically, seeds have been available free of charge to farmers through multiplication and reuse. It was difficult for seed breeders to obtain a return which justified investment in innovation, so development of new varieties was mainly the domain of public institutions. With the introduction of hybrid corn varieties in the 1930s, corn growers no longer saved seed, as hybrid seed does not breed true to type. As long as the lineage of a hybrid was unknown to competitors or farmers, the breeder

continued to hold a unique and marketable product until an even better hybrid was developed. The introduction of hybrid corn encouraged the formation of private companies to produce corn seed in the 1930s (Fernandez-Cornejo 2004). However, for breeders of Open Pollinated Varieties (OPVs) the lack of return to innovation discouraged private investment in research.

2.1 Plant Variety Protection in the US

In 1970, in response to pressure from plant breeders, the Plant Variety Protection Act (PVPA) was enacted to extend PVP to OPVs. PVP Certificates provide protection for a period of 20 years from the date of issue. Stronger protection became available in the mid 1980s when a series of court decisions opened the way for plant breeders to take out utility patents over life forms, held to include plant varieties, breeding methods and gene sequences. A utility patent provides protection for 20 years from date of application. On average the interval from application to approval for corn varieties and inbred lines is about 28 months, so the effective protection period is about 17.5 years (USPTO 2008). The PVP regime includes a research exemption, but this does not apply for utility patents. A variety may be protected by both a patent and a PVP Certificate at the same time. The Plant Breeders Rights (PBR) regime, whether through patents or PVP, does not involve any form of quality control. New varieties must be different, but they need not be proven to be superior to existing varieties. However field testing is required where Genetically Modified (GM) organisms are introduced (Fernandez-Cornejo 2004). Although corn seed is hybrid seed, breeders have considered it worthwhile to take advantage of the protection offered by the PBR regime.

2.2 Plant Variety Protection in the EU

The system in the EU differs from that in the US. While it is possible to patent life forms, it is not possible to hold a patent and a PVP certificate for the same variety (Wurtenberger *et al.* 2006). The general practice is to use patents to protect methods, and PVP to protect varieties. The EU PVP provides protection for 25 years from date of issue of the certificate. The process is linked with the seed certification process, so that effectively varietal rights are only available for cultivars which are demonstrably superior. Breeders can apply for protection to national bodies in each of the EU member countries, or to the Community Plant Variety Office (CPVO) for protection EU-wide. If CPVO protection is taken out for a variety that is already registered in an individual member country, the individual country protection becomes dormant, but

can be reactivated if the CPVO protection is terminated (Wurtenberger *et al.* 2006). The terms and conditions, but not necessarily the costs, of protection are similar for the individual countries and the CPVO.

3. Expected effects of the introduction of IPRs for plant breeding

IPRs regimes for plant breeding have been justified by their supporters on the basis that they encourage both innovation and the dissemination of knowledge. They may however reduce public investment in plant breeding and lead to an increase in market power.

3.1 Innovation and dissemination of knowledge

It is possible that without IPRs protection, an innovator will have no incentive to act. If one of the inputs is a public good (such as a technological advancement) the good can be used repeatedly without repeating the development expenditure. The production function will exhibit increasing returns to scale. If output is priced at marginal cost the firm will not cover the Research and Development (R&D) and regulatory costs of developing the technological advance, and will not survive as a price taker. If returns to private investment are inadequate, R&D can be carried out by public agencies, or IPRs can be introduced to encourage innovation by allowing private enterprise (in the present case private seed breeders) to obtain property rights through the creation of excludable goods (Fulton 1997). A further argument in favour of IPRs is that breeders are required to make information about their innovation publicly available as a condition of obtaining protection. This is said to add to welfare by increasing the dissemination of knowledge (Lence *et al.* 2003).

3.2 Shift from public to private breeding

Because of the incentives provided to private breeders under IPRs regimes, their introduction is likely to lead to a rise in the proportion of private investment in research at the expense of public investment. Reduction in the share of publicly funded plant breeding could be attributed to a number of factors. The first could be, quite simply, less funding. The second could be that because private firms have IPRs, and therefore incentive to innovate, they are prepared to spend more on research. The third is that while there is a research exemption for varieties protected under the PVPA, there is no such exemption for varieties or other life forms protected by utility patents. The Freedom to Operate of public plant breeders is restricted because they no longer have unrestricted access to genetic material.

3.3 Increase in market power

With the increase in private funding of research, the input of publicly developed inbred lines into modern varieties has declined. Previously, most breeders of corn used publicly developed inbred lines in the breeding process. Modern varieties are overwhelmingly crosses of private inbred lines, so the choice of alternative sources of germplasm has become more limited. Choice of supplier will also be reduced if there is an increase in market concentration, leading to an increase in the ability of the firms in the industry to exercise market power. Firms will be able to exercise market power if markets are not contestable. A market will not be contestable if a firm obtains a patent on a technology which is an essential input into production, thus creating barriers to entry to the industry, or if the industry is characterised by high sunk costs, meaning that there are costs to entry and exit (Fulton and Giannakas 2001). There are concerns that increased market power may lead to business practices that abuse that power.

4. The US and EU corn seed industries since 1970

4.1 Innovation

There is some evidence that, contrary to expectation, the introduction of IPRs for plant varieties may have reduced research intensity¹ into crop biotechnology rather than encouraging innovation (Fernandez-Cornejo and Schimmelpfennig 2004; Schimmelpfennig *et al.* 2004). It is suggested that this may be because the introduction of IPRs has encouraged consolidation, leading to less competition in R&D. Alston and Venner (2002) found that the PVPA had not contributed to increases in wheat yield, or an increase in private investment in wheat breeding. Brennan *et al.* (2005) argue that leading biotech firms have the ability to decrease total industry investment in R&D because of the concentration of patent ownership, and there are concerns that the cost of obtaining permission to use patented technology may prevent some firms participating in innovative research (Graff *et al.* 2004). The supposed value of increased public availability of knowledge under IPRs could perhaps be questioned in the case of PVP or PBR, given that a variety (with its associated increase in knowledge) is likely to be superseded well before the expiry of the protection. Shi *et al.* (2008) suggest that the average life of a hybrid corn variety is now only about three years.

4.2 Move to private plant breeding

¹ Defined in these papers as the annual number of field trial applications from private firms divided by private industry sales of seed for each major crop (in millions of dollars)

As could be expected, research into commercially profitable plant varieties has moved from the public to the private sector. Fernandez-Cornejo (2004) suggests that private R&D expenditures on US plant breeding as a whole rose by 1300 per cent between 1960 and 1996 (adjusted for inflation), while real public R&D changed very little. The situation is hard to assess because of the lack of suitable data. While total R&D expenditure of firms is available the proportion spent on new plant variety generation is not known (Srinivasan *et al.* 2002). Studies in 1994 and 2001 used survey data in an attempt to determine the relative shares of effort in those years (Frey 1996; Traxler *et al.* 2005). The 1994 study provided some insight into private breeding, but the private sector response in 2001 was so poor that the authors did not report on private research. Fuglie and Heisey (2007) note that analysts have not been able to track private sector investments in agricultural research since 1998 due to unavailability of comparable data.

More concrete evidence for the shift from public to private plant breeding in the corn seed industry is provided by Darrah and Zuber (1986) and Mikel and Dudley (2006). They note that hybrids with only public inbred lines were used for 24 per cent of US corn production in 1979, and only 6 per cent by 1984. Mikel and Dudley (2006) searched of USPTO and PVPO databases and demonstrated that public inbred lines were used in development of 45 per cent of new US corn inbreds from 1980-1988, 10 per cent from 1988 to 1996, and only 2 per cent from 1997 to 2004.

4.3 *Effect of high entry costs and regulatory barriers to entry*

The substantial costs of R&D, and the existence of an IPRs regime, mean that there are sunk costs and barriers to entry for the private plant breeding industry, and that therefore seed markets are not contestable. The time required to produce a new variety of corn is estimated at 6 to 15 years, depending on the genetic resources available to the breeder and the type of hybrid (Lopez-Pereira and Garcia 1997). Of 10000 crosses about 100 lines are developed, and of these only about three become part of a commercial hybrid (McMullen 1987). As previously mentioned, Shi *et al.* (2008) suggest that the effective life of a hybrid corn seed is now about three years. The costs of introducing a new Bt corn variety, MON810, to one market (The Philippines) were estimated at \$US2.6 million at 2004 discounted prices (Manalo and Ramon 2007). This estimate allocated core development costs incurred in the US to the Philippines based on the country's share of total world production of the variety.

Breeders are unlikely to make the required investment in development of varieties without protection, and the costs of obtaining PVP or patent protection are low by comparison with the development costs. The cost of lodging an application for a patent or PVP certificate in the US is estimated at \$US50 000 (Phil Pardey, Pers. Comm. 2008). The fees for applications for patents and PVPs, and for their maintenance, range from \$US5000 to \$US10000, depending on country and regime (CPVO 2008a; DEFRA 2008; PVPO 2008a; USPTO 2008a). The disparity between costs of development and cost of protection could be expected to make the decision to protect relatively straightforward.

5 The current structure of the United States and EU corn seed markets

5.1 The US market

Until the 1970s the US corn seed market was relatively unconcentrated. The four-firm concentration ratio (CR4) was estimated as 60 per cent in 1983 and 69 per cent in 1997 (Fernandez-Cornejo 2004). Pioneer controlled 42 per cent of the market, Monsanto 14 per cent and Novartis 9 per cent (Fernandez-Cornejo 2004). Smaller firms still had 20 per cent. It is difficult to determine market share in a fashion that is consistent and comparable over a number of years, since information is commercially sensitive, and companies report sales and returns in different ways.

The main participants in the corn seed market today are Pioneer HiBred (DuPont), Monsanto, Syngenta and Dow. Pioneer has been breeding corn seed since 1921, and owns a large bank of genetic material but is not strong in biotechnology traits. Its 1999 merger with DuPont was designed to address this problem. Monsanto was a chemical company which acquired Asgrow, DeKalb and Holden's Foundation Seeds between 1997 and 2000 to obtain germplasm into which it could insert biotechnology traits. Syngenta is European based, and was formed through the merger of Novartis and the agricultural operations of Astra Zeneca in 2000. In 2004 Syngenta purchased J.C. Robinson, Golden Harvest, Garst, and the US operations of Advanta. Dow has continued to expand in the US, buying the US operations of Cargill in 2000 and Triumph Seed in 2008, and in Europe and Brazil (information extracted from various sources).

While Pioneer has traditionally had the largest share of the market, the increase in planting of GM corn from 25 per cent of all plantings in 2000 to 80 per cent in 2008 (USDA NASS 2008) has had an effect on market rankings. In 2006 and 2007 Pioneer's share of the corn seed market was about 30 per cent (E.I. DuPont de

Nemours 2006, 2007), compared with the 42 per cent previously quoted (Fernandez-Cornejo 2004). It appears that growers are demanding seed of GM varieties, and the company does not have sufficient supplies to meet that demand. Monsanto, which according to some (for example, Barboza 2003) controls over 90 per cent of biotechnology traits, now claims more than 64 per cent of the United States corn seed market (40 per cent seed sales and 24 per cent licensing) (Monsanto 2008). Possibly as a response to the increasing market share of Monsanto, Pioneer and Syngenta formed a joint venture in 2006 to license corn and soybean traits to other companies for the US market, giving Pioneer a global licence to Syngenta's insect resistant technology, and Syngenta a global licence to the herbicide tolerant technology. Dow and Pioneer have jointly developed insect protection, but are marketing them separately. The market is therefore more concentrated than might appear from shareholdings. The CR4 will be unaffected by the changes in ranking or the joint operations.

5.2 The EU market

The corn seed market in the EU is less concentrated than in the US, although the major US seed companies operate in Europe. There are a number of well-established French farmer-based cooperatives which have a large share of the market, and some small independent breeders, particularly in Germany and Italy. With the expansion of the EU, a substantial number of varieties from independent Eastern European breeders are included in the EU databases. Because of the range of climatic conditions in Europe, the late maturing varieties of corn which characterise the US industry are not suitable for the whole of Europe. Early maturing or green corn varieties are required for the north. The merger and acquisition (M&A) activity in the US corn seed industry since 1996 appears to have been substantially driven by the introduction of GM crops. The barriers to introduction of GM varieties into European agriculture may have had an effect in slowing down M&A. Eight members of the EU27 planted GM crops in 2007 (James 2007). It has also been suggested that because European policy aims to promote Small-to-Medium-sized Enterprises (SMEs), biotechnology-based SMEs can provide lower-cost R&D services to the seed breeding companies (Mangematin *et al.* 2001).

6 Data Sources

We are interested in investigating the effects of IPRs on innovation and welfare distribution in the corn seed industry where there is likely to be less than perfect competition. There have been some empirical and theoretical studies of industries where inputs are sold in a non-competitive market to the competitive farm sector (for example, McCorrison 1993; Moschini and Lapan 1997; Fernandez-Cornejo and Spielman 2002). However, any updated study of the effects of increased market concentration requires updated data. Sexton (2000) notes that lack of recent data is a common problem with studies of market power in the agricultural marketing chain, and points out that studies based on old data sets may understate the extent of market power. New data are required because of the substantial change in the structure of the corn seed market in the US since the late 1990s.

Given the difficulties in obtaining consistent and comparable data for market share, it may be useful to consider alternatives. Fulton and Giannakas (2001) suggest that share of sales may not always be the most appropriate measure of market power in an industry. The Federal Trade Commission has used innovation competition to assess the impact of mergers (Brennan *et al.* 2000; Fulton and Giannakas 2001). Brennan *et al.* (2000) use data from field trials to calculate a CR4 for improved seed at the R&D stage, and find that the concentration at the R&D stage is matched by concentration in terms of number of patents held. Brennan *et al.* (2005) have estimated concentration in GM innovation using biotechnology patent data.

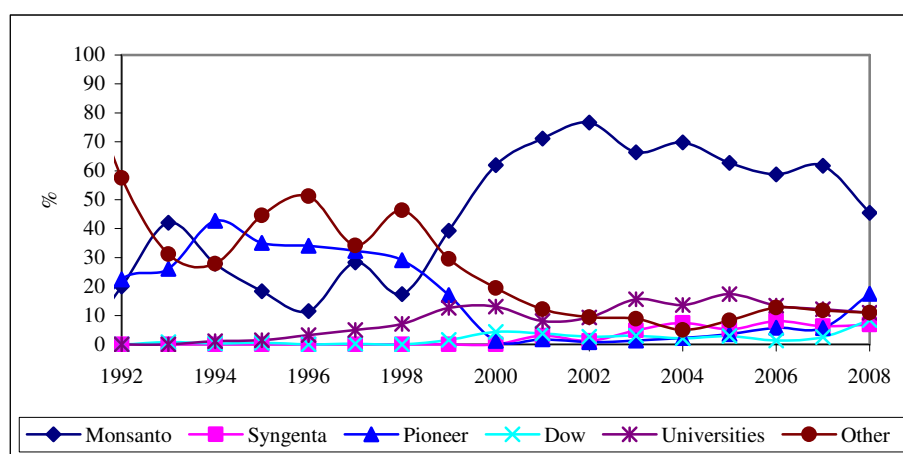


Figure 1 Percentage of Field Trial Applications per company for Biotech Corn Varieties

6.1 Field trial applications

The percentage share of field trial applications made to the USDA Animal and Plant Health Inspection Service (Animal and Plant Health Inspection Service (APHIS) 2008) by company since 1992 is shown in Figure 1.

There are some problems with relying on field trial applications as a measure of market concentration. The applications are only required for GM varieties, and it is possible for companies to petition for deregulation of GM organisms. Twenty-two organisms used in corn breeding have been deregulated since 1995 (APHIS 2008). These trials do not represent all corn varieties being introduced. It is also difficult to be sure what exactly is being trialled because of “business in confidence” considerations (applicants do not yet have IPRs protection, and therefore the information publicly available is limited). The applicant may not be the eventual assignee of any resulting patent or PVP certificate, so that although there is a reasonable proportion of field trial applications from universities, they may be acting in collaboration with private breeders who may ultimately be assigned the patent or other protection.

6.2 US Patents and PVP Certificates Issued

Another possibility is to use the proportion of germplasm, the essential input for corn seed production, owned by each company as a proxy for changing levels of market concentration. As previously mentioned, Brennan *et al.* (2005) have measured concentration in innovation by calculating share of biotechnology patents owned by each company. As far as we are aware, this approach has not been used to determine market concentration for an individual crop, although it is acknowledged that concentration ratios will vary between crops. To obtain a complete picture it is necessary to also include PVP certificates for corn. From the database of the USPTO (USPTO 2008b), and records of the USPVPO (USPVPO 2008b), we have details of assignees of patents and PVPA certificates for corn seed. At 7 April 2007, 1497 utility patents for corn seed had been issued by the USPTO since 1985. Of these, 479 were related to methods rather than varieties, and have been disregarded for the purposes of this study. Of the remaining 1018 patents, 720 related to inbred lines and 298 to hybrid corn varieties. From the early 1970s until 7 April 2007, 779 PVP certificates for varieties and inbred lines had been issued. Of these, 435 were also covered by patents, and were excluded. This left 1362 corn varieties and inbred lines which have, or had, some form of IPRs protection in the US either through patents or through PVP. Of these 835 were inbred lines, and 524 were varieties.

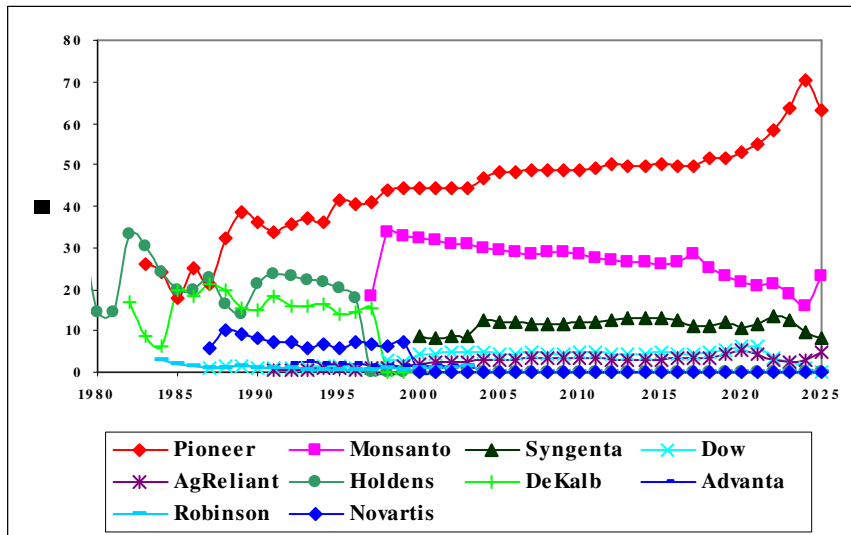


Figure 2 Percentage share of patents and PVPs 1980-2025F

From the application and issue dates, and hence the expiry dates, we have determined the ownership of germplasm with IPRs protection from 1976 until 2007, with projections to 2025. The percentage ownership can be seen in Figure 2. We have adjusted the data to account for changes in beneficial ownership through M&A activity from 1976 to the present, and have assumed that existing patents will be maintained over the projected period. While these projections do not take into account the possibility of new entrants, the 160 patents issued for inbred lines or varieties in the following 12 months to April 2008 were all assigned to the top four companies.

While germplasm will be available for public use once patents have expired, if the life span of a cultivar is only three years, this information may not be useful in 18 to 20 years when the protection expires. The life of an inbred line will depend on its quality, and it is conceivable that it may outlast its patent. It will be difficult for new entrants to use the published information to enter the industry.

It can be seen from Figure 3 that the CR4 for corn, based on ownership of germplasm through patents and PVPA certificates, was 94 per cent in 2007. This is considerably higher than the value of approximately 70 per cent quoted in other studies. While we acknowledge that these data have limitations (for example it would be useful to assign a weighting based on the extent of adoption of a variety or the use of an inbred line) we suggest that it may at least provide an alternative to unreliable market share data.

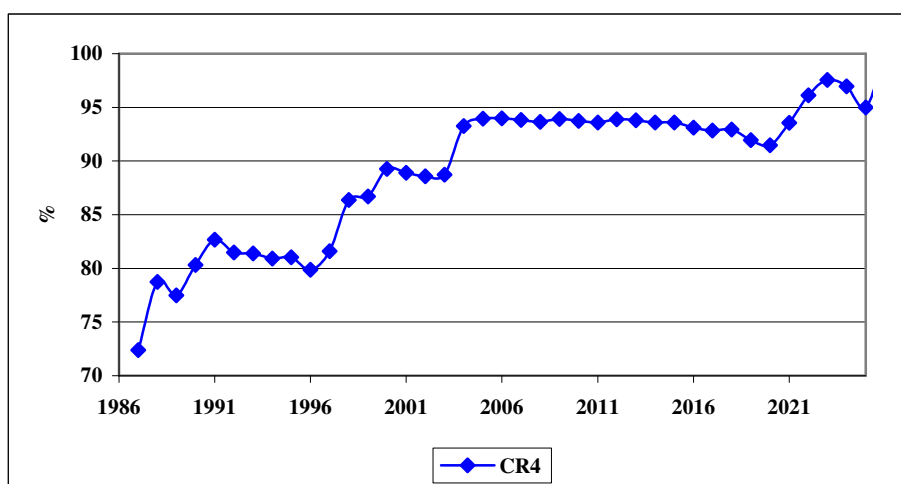


Figure 3 CR4 for corn inbred lines and varieties based on share of ownership of germplasm

6.3 EU PVP Certificates

For the purposes of comparison, the share of PVP certificates by company at 30 June 2007 for four European companies and for the EU27 is given in Table 1 (Extracted from CPVO 2008b; GNIS 2008), and it can be seen that this market is currently less concentrated than that in the US. The ranking, and the CR4, is variable between

Table 1 Percentage shares of PVP Certificates for corn varieties in the EU at 30 June 2007

Company	France	Germany	Spain	Italy	EU27
Limagrain	21.2	19.3	20.1	13.9	16.5
Syngenta	12.0	6.4	7.1	14.8	14.64
Pioneer	19.6	26.2	26.3	17.1	12.13
Monsanto	9.2	8.2	10.2	13.7	10.85
KWS	13.5	19.7	13.8	10.4	10.81
Euralis	8.0	4.8	5.5	7.1	7.1
RAGT	9.7	9.8	9.6	6.0	5.69
Caussade	4.2	2.3	2.1	4.7	3.98
Dow	0.4	0.6	0.6	2.0	1.16
Other	2.3	2.7	4.7	10.3	17.14
CR4	66.3	75.0	70.4	59.5	54.12

member countries. To put these figures in context, it should be noted that the EU has about 10 per cent of total world seed maize acreage, behind the US and China, each with 33 per cent. In 2006 France had 48 per cent of the EU acreage and Hungary 27

per cent. Ninety-four per cent of France's seed maize exports go to EU countries, mainly Germany and the Benelux countries (AGPM 2008). We are in the process of calculating the shares in the EU over the same time period as for the US data.

7 Conclusion

Seed is an essential input into food production. It is no longer a free or almost free input in developed countries. With technological progress, the cost of seed has increased relative to that of other inputs in the United States. There are no up-to-date, accurate measures of the possible contribution of the existence of an IPRs regime to the increase in costs. Studies are generally theoretical, or based on data which do not take into account the consolidation that took place at the end of the 1990s and which is still occurring. If there have been adverse effects of IPRs /PBR for food producers and/or consumers in the US and the EU, it would be useful to quantify them as a guide to what could be expected to happen if the rest of the world adopted and enforced PBR. In this paper we update company and market information, and propose, given that germplasm is the critical input into a seed variety, that PVP and patent data could be used to determine who has control over that critical input, and to provide an alternative measure of market concentration. Preliminary work suggests that a CR4 calculated using this data is considerably higher than reported for the corn seed industry in other studies. This alternative measure will be the basis of future work.

8 References

Alston, J. and Venner, R. (2002). The effects of the US Plant Variety Protection Act on wheat genetic improvement, *Research Policy* 31, 527-542.

Animal and Plant Health Inspection Service (APHIS) (2008). *Field Test Release Applications in the U.S.* Database Provided by APHIS Biotechnology Regulatory Services. Available from <http://www.isb.vt.edu/cfdocs/fieldtests1.cfm>: [Accessed on various dates in 2007 and 2008]

Association Générale des Producteurs de Maïs (AGPM) (2008). The Maize Market & Economy: Seed Maize. Available from URL: http://www.agpm.com/marche_eco/en/chiffres_production_maïs.php. [Accessed on various dates in 2008]

Barboza, D. (2003). Monsanto Struggles Even as It Dominates, *New York Times*, May 31

Brennan, M., Pray, C. and Courtmanche, A. (2000). Impact of Industry Concentration on Innovation in the U.S. Plant Biotech Industry, in Lesser, W. (Ed), *Transitions in Agbiotech: Economics of Strategy and Policy: Proceedings of NE-165 Conference, 24-25 June, 1999*. Vol. 2, Food Marketing Policy Center, Department of Agricultural and Resource Economics, University of Connecticut, and Department of Resource Economics, University of Massachusetts, Washington D.C.

Brennan, M., Pray, C., Naseem, A. and Oehmke, J. (2005). An Innovation Market Approach to Analyzing Impacts of Mergers and Acquisitions in the Plant Biotechnology Industry, *AgBioForum* 8, 89-99.

Community Plant Variety Office (CPVO) (2008a). Applicable Fees. Available from URL: <http://www.cpvo.eu.int/main/en/home/methods-of-payment/applicable-fees>. [Accessed on various dates in 2008]

Community Plant Variety Office (CPVO) (2008b). *Applications and Titles in Force*. Available from <http://www.cpvo.eu.int/main/en/home/databases/applications-and-titles-in-force>: [Accessed on various dates in 2007 and 2008]

Darrah, L. and Zuber, M. (1986). 1985 United States Farm Maize Germplasm Base and Commercial Breeding Strategies, *Crop Science* 26, 1109-1113.

Department for Environment Food and Rural Affairs (DEFRA) (2008). PVS: Plant Breeders' Rights: Application Procedure. Available from URL: <http://www.cpvo.eu.int/main/en/home/methods-of-payment/applicable-fees> [Accessed on various dates in 2008]

E.I. DuPont de Nemours (2006). *Form 10-K*. United States Securities and Exchange Commission. Washington D.C.

E.I. DuPont de Nemours (2007). *Form 10-K*. United States Securities and Exchange Commission. Washington D.C.

Fernandez-Cornejo, J. (2004). *The Seed Industry in US Agriculture*. Number 786, Economic Research Service, USDA, Washington D.C.

Fernandez-Cornejo, J. and Spielman, D. (2002). Concentration, Market Power and Cost Efficiency in the Corn Seed Industry, Paper presented at the 2002 Annual Meeting of the American Agricultural Economics Association, Long Beach, California.

Fernandez-Cornejo, J. and Schimmelpfennig, D. (2004). Have Seed Industry Changes Affected Research Effort?, *Amber Waves* 2.

Frey, K. (1996). *National Plant Breeding Study - 1: Human and Financial resources Devoted to Plant Breeding Research and Development in the United States in*

1994. Special Report 98, Iowa Agriculture and Home Economics Experiment Station, Iowa State University.
- Fuglie, K. and Heisey, P. (2007). *Economic Returns to Public Agricultural Research*. Economic Brief Number 10, Economic Research Service. Washington D.C. Available from URL: <http://www.ers.usda.gov/publications/eb10/eb10.pdf>
- Fulton, M. (1997). The Economics of Intellectual Property Rights: Discussion, *American Journal of Agricultural Economics* 79, 1592-1594.
- Fulton, M. and Giannakas, K. (2001). Agricultural Biotechnology and Industry Structure, *AgBioForum* 4, 137-151.
- Graff, G.D., Rausser, G.C. and Small, A.A. (2003). Agricultural Biotechnology's Complementary Intellectual Assets, *Review of Economics and Statistics* 85, 349-363.
- Graff, G.D., Wright, B., Bennett, A. and Zilberman, D. (2004). Access to intellectual property is a major obstacle to developing transgenic horticultural crops, *California Agriculture* 58, 120-126.
- Groupement National Interprofessionnel des Semences et Plants (GNIS) (2008). *Catalogues européens des espèces de grandes cultures et plants de pomme de terre*. Available from http://www.gnis.fr/index/action/page/id/256/title/Catalogues_europeens: [Accessed on various dates in 2007 and 2008]
- Harhoff, D., Regibeau, P., Rockett, K., Schnitzer, M. and Jullien, B. (2001). Some Simple Economics of GM Food, *Economic Policy* 16, 265-299.
- James, C. (2007). *Executive Summary: Global Status of Commercialized Biotech/GM Crops: 2007* International Service for the Acquisition of Agri-Biotech Applications. Ithaca, New York.
- King, J. and Schimmelpfennig, D. (2005). Mergers, Acquisitions, and Stocks of Agricultural Biotechnology Intellectual Property, *AgBioForum* 8, 83-88.
- Lence, S., Hayes, D., McCunn, A., Smith, S. and Niebur, B. (2003). Welfare Impacts of Property Rights in the Seed Industry, Paper presented at the American Agricultural Economics Association Annual Meeting, Montreal, Canada.
- Lopez-Pereira, M. and Garcia, J. (1997). *The Maize Seed Industries of Brazil and Mexico: Past Performance, Current Issues, and Future Prospects*. 97-02, CIMMYT. Mexico. Available from URL: <http://www.cimmyt.org/english/wps/publs/catalogdb/catalog.cfm>
- Manalo, A. and Ramon, P. (2007). The Cost of Product Development of Bt Corn Event MON810 in the Philippines, *AgBioForum* 10, 19-32.
- Mangematin, V., Lemarié, S. and Catherine, D. (2001). French ag-biotech SMEs: Development prospects, *AgBioForum* 4, 98-104.

- McCorrison, S. (1993). The welfare implications of oligopoly in agricultural input markets, *European Review of Agricultural Economics* 20, 1-17.
- McMullen, N. (1987). *Seeds and World Agricultural Progress*. Vol. Washington D.C., National Planning Association.
- Mikel, M.A. and Dudley, J.W. (2006). Evolution of North American Dent Corn from Public to Proprietary Germplasm, *Crop Science* 46, 1193-1205. Available from URL: <http://crop.scijournals.org/cgi/content/abstract/cropsci;46/3/1193>
- Monsanto (2008). Supplemental Tool Kit for Investors. Available from URL: http://www.monsanto.com/pdf/investors/supplemental_toolkit.pdf. [Accessed on 20 November 2008]
- Moschini, G. and Lapan, H. (1997). Intellectual Property Rights and the Welfare Effects of Agricultural R&D, *American Journal of Agricultural Economics* 79, 1229-1242.
- Plant Variety Protection Office (PVPO) (2008a). PVPO Services and Fees. Available from URL: <http://www.ams.usda.gov/AMSV1.0/ams.fetchTemplateData.do?template=TemplateN&navID=PVPOServicesandFees&page=PVPOServicesandFees&description=PVPO-Services%20and%20Fees>. [Accessed on various dates in 2008]
- Plant Variety Protection Office (PVPO) (2008b). *Plant Variety Protection Office - Scanned Certificates* Available from <http://apps.ams.usda.gov/PVPO/CertificateDatabase/pvplist2.asp>: [Accessed on various dates in 2007 and 2008]
- Schimmelpfennig, D., Pray, C. and Brennan, M. (2004). *The Impact of Seed Industry Concentration on Innovation: A Study of U.S. Biotech Market Leaders*. SSRN. Available from URL: <http://ssrn.com/paper=365600>
- Sexton, R.J. (2000). Industrialization and Consolidation in the U.S. Food Sector: Implications for Competition and Welfare, *American Journal of Agricultural Economics* 82, 1087-1104.
- Sheldon, I. (2008). The Biotechnology Sector: "Bounds" to Market Structure, Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Orlando, Florida. July 27-29.
- Shi, G., Chavas, J.-P. and Stiegert, K.W. (2008). *An Analysis of Bundle Pricing: The Case of the Corn Seed Market*. Working Paper Series FSWP2008-01, Food System Research Group, University of Wisconsin-Madison. Available from URL: <http://ssrn.com/paper=1272132>
- Srinivasan, C., Shankar, B. and Holloway, G. (2002). An Empirical Analysis of the Effects of Plant Variety Protection Legislation on Innovation and Transferability, Contributed paper submission for the triennial meetings of the European Association of Agricultural Economists, Zaragoza, Spain.

- Traxler, G., Acquaye, A., Frey, K. and Thro, A. (2005). *Public Sector Plant Breeding Resources in the US: Study Results for the year 2001*. ERS. Washington.
Available from URL:
http://www.csrees.usda.gov/nea/plants/pdfs/plant_report.pdf
- United States Patent and Trademark Office (USPTO) (2008a). 2008 Fee Schedule
Available from URL: <http://www.uspto.gov/main/howtofees.htm>. [Accessed on April 2008]
- United States Patent and Trademark Office (USPTO) (2008b). *Patent Full-text and Full-Page Image Databases*. Available from <http://patft.uspto.gov/>:
[Accessed on various dates in 2007 and 2008]
- USDA National Agricultural Statistics Service (NASS) (2008). Adoption of Genetically Engineered Crops in the US: Corn Varieties. Available from URL:
<http://www.ers.usda.gov/Data/BiotechCrops/ExtentofAdoptionTable1.htm>.
[Accessed on various dates in 2008]
- Wurtenberger, G., Van der Kooij, P., Kiewiet, B. and Ekvad, M. (2006). *European Community Plant Variety Protection*. Oxford University Press, Oxford.