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EVALUATING AGRICULTURAL RESEARCH AND PRODUCTIVITY IN AN ERA OF RESOURCE SCARCITY

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Impact of Changing Intellectual Property Rights on U.S. Plant Breeding R&D

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I. Introduction

The Plant Variety Protection Act (PVPA) and the application of utility patents (UPs) to plants are currently the topic of considerable controversy among plant breeders, business people, environmentalists and others. The primary goal of the seed industry is eliminate "farmers rights" to sell protected varieties. Seed firms feel they are losing money because seed firms posing as farmers are selling protected varieties without permission from or royalties to the owner. A second goal of the seed industry is to strengthen the rights of variety owners by disallowing certificates for varieties that have only minor changes. This goal is embodied in the clause on "essentially derived" varieties in the 1991 UPOV treaty.

Public sector scientists and some private firms are concerned that the application of utility patents to plants will have a negative impact on the exchange of information and germplasm between scientists within the U.S. and world wide.

In order to decide whether the U.S. should strengthen or weaken current intellectual property rights on plants, policy makers need information on the impact of IPRs on public and private research. This paper attempts to measure the impact of recent changes in IPRs on the amount and direction of U.S. private R&D.

II. Model of R&D by Private Firms

To place IPRs in their proper perspective it is important to remember that they are only one factor a firm considers when investing in a research program. In fact, the primary factors in many early models of R&D, which were based on the work of Schumpeter, were firm size and market power. In these models the larger the firm the more research it conducts both in absolute terms and as a percentage of sales or other measures of firm size. Many of the early empirical studies in this literature found an inverted U shaped relationship between R&D and firm size, with small and large firms spending less R&D per sales than the medium size firms.

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The role of demand in influencing investment in R&D was emphasized by Schmookler (1966) in several important studies in the 1960s. He tried to show that the growth in demand in an industry stimulated R&D with a certain time lag.

More recent studies have incorporated Schmookler's ideas on the role of demand and have divided the Schumpeterian emphasis on industry structure into two factors: appropriability and technological opportunity. Thus, the three main factors influencing a private firm's investment in research to develop new products are: (1) the expected demand for the products; (2) the technological opportunity for developing new products through research and (3) the ability of the firm to appropriate some of the benefits which users of the new products receive (see Griliches 1984).

The demand for new varieties of crops is a derived demand based on the expected demand for the crop and the productivity of the new variety. The quantity demanded is also influenced by farmers' ability to reproduce seed of the crop. Some crops like alfalfa are virtually impossible for farmers in many regions to produce themselves while other seeds such as wheat and rice are easy to reproduce and store.

The technological opportunity for firms to develop new varieties depends on the costs of the research inputs, the skill and level of technology used by their plant breeders, and the germplasm and information available from public research, from other private research and abroad. The major change in technological opportunity in recent years is the application of molecular biology to plant breeding. This has increased the productivity of conventional plant breeding and led to the production of transgenic plants with genes from other species and even from bacteria and animals. Technological opportunity can also be changed by changes in the spillovers of information from other firms and the public sector due to changes in intellectual property rights. The more easily germplasm and information are available from other firms and government research programs, the more research a firm will do ceteris paribus.

Appropriability is a function of the firm's ability to keep other seed companies and farmers from duplicating or making close substitutes for their variety. It is thus a function of the technical characteristic of the variety, the structure of the seed industry, and intellectual property rights. Firms have greater appropriability in crops in which hybrid varieties are used[2]. Firms can, with careful management, keep the parental lines of hybrids secret, and farmers and other seed companies can not

[2] Primarily crops that are naturally cross pollinated such as maize, sorghum, pearl millet and sunflower.

produce hybrid seed by simply multiplying hybrid material purchased from the owners of the hybrid. Without intellectual property rights firms have little appropriability of new pure line varieties[3]. Farmers and seed companies can easily reproduce such new varieties.

Intellectual property rights provide firms the right to exclude other firms and farmers from reproducing the varieties which they develop. This gives the firm a temporary monopoly on the sale of the protected variety which allows the firm to charge higher prices for seeds of the variety than if other firms are also selling the variety. In this way the firms profit from the research they used to produce the new variety.

The concept of patents contains a built in contradiction. Spillovers stimulate research because they increase the productivity of each firm's research - in other words they increase technological opportunity. However, more spillover means less appropriability and this may discourage research. This is precisely the debate that is going on between scientists over whether plants should be patentable under the utility patent law. Those who oppose it fear that the spillovers allowed under PVPA will be eliminated since there is no explicit research exemption in utility patent law. Economic theory provides little help. Thus, empirical research is necessary to determine the impact.

III. IPR Laws Covering Plants

A Legislation

The Plant Patent Act (PPA) when passed in 1930 was the first legislation to provide intellectual property rights in plants. It covered new and distinct asexually propagated varieties excluding tuber-propagated plants such as potatoes. Application forms are straight forward and can be filled out by breeders. More than 80 percent of the applications are approved. Table 1 presents a summary of the coverage and characteristics of different types of IPRs.

The U.S. Plant Variety Protection Act (PVPA), which was passed in 1970, provides owners with the exclusive rights for 18 years to novel, sexually propagated varieties and inbred lines of hybrids. The U.S. Department of Agriculture (USDA), which administers PVPA, checks applications against the descriptions of varieties in its data bank. If the variety is assessed to be different, a certificate is issued. PVPA has two explicit exemptions from protection. First, farmers can reproduce seed for themselves and sell seed as long as seed sales are less than 50 percent of total production of that variety on their farm. Second, the owners of a

[3] Pure line varieties are normally produced in naturally self-pollinated crops, such as wheat and rice.

variety can not prevent researchers from other companies or public agencies from using that variety to produce a new variety.

Like Plant Patents PVPA application forms are straight forward and can be filled in by breeders. About 90 percent of PVPA applications are approved.

Plant varieties, engineered genes, and hybrid varieties have been subject to utility patents since the *Ex parte Hibberd* ruling by the Patent and Trademark Office's Board of Patent Appeals and Interferences in 1985. UPs provides exclusive rights for 17 years for inventions that are novel, nonobvious to others in the field and useful. Protection can be much broader than under PVPC or Plant Patents. It can include a group of varieties that all have the patented characteristics while only individual varieties could be patented under PVPA. No explicit research or farmers exemptions exist in UPs. Farmers can not sell seed and theoretically farmers must pay royalties to the holder of the UP if they plant the variety as second year using their own saved seed. Scientists who use a patented variety to produce another commercial variety could either be prevented from selling the second variety or would have to pay a royalty to the owner of the first variety.

Patents are unlike Plant Patents and PVPA in several key aspects. They require enabling disclosure of the inventions so that other can use the knowledge to make other inventions. The U.S. Patent Office requires a deposit of seed, if a variety is being patented and this seed must be made available to others for research use. Patent applications are different in that they usually require lawyers to fill out the forms which increases the cost of applying considerably. Of the applications which include claims on plants 22 percent have been granted. In addition it takes several years to grant patents while only a few months are required for PPs and PVPCs.

There is no explicit research exemption in UP law. However, the courts recognize the right of legitimate research who are not attempting to produce a commercial product with their research to use patented products in research. In addition since a patent case takes about four years and costs about $1 million a year few companies will take researchers to court unless they think the researchers will seriously cut into their market.

Trade secrets are the fourth type of IPR that are used to protect plants. Trade secrets are governed by state laws, but they go back to the English common law tradition. They provide protection for an invention as long as the secret is not disclosed in a nonconfidential manner. They have primarily been used to protect F1 hybrids in which the inbreds lines are kept secret.

Table 1. Comparison of IPRs of Plants

	PPA	PVPA	Utility Patents	Trade Secret
Coverage				
Asexually Propagated Variety[1]	Yes	No	If large inventive	No
Sexually Propagated Variety	No	Yes	If large inventive step	No
Hybrid Variety	No	No	Yes	Yes
Engineered Gene	In protected Variety		Yes	Until Disclosed
Phenotypic characteristic in different varieties or crops	No	No	Yes	No
Cost of application	Low	Low	High	---
Percent of applications accepted	84	90	22	---

1. Excludes tuber propagated crops

B. Case Law

Case law and rulings by the patent system have evolved to help define the protection offered to plant breeders. To enforce the U.S. PVPA firms must identify violators and bring them to court to seek injunctions against further infringement, royalties and punitive fines. Adherence to the law has varied over time. When the law was passed, firms ran a publicity campaign to educate farmers and other firms about the provision of the law. In most cases when companies discovered violations, they just needed to write the farmers or cooperatives informing them about the provisions of law and the violations stopped. Adherence to the law weakened gradually. Specific cases defined farmers rights more broadly than most companies wished. For example, Asgrow vs. Kunkle 1987 found that even very large sales by farmers were legal as long as the farmer sold less than 50% of his crop as seed for reproductive purposes. The weakness of the law were emphasized recently by Pioneer Hi-Bred's well publicized closure of its hard red winter and hard red spring wheat program (Newlin).

In contrast to the self pollinated crops, property rights for corn and other hybrids and potatoes were strengthened during the 1980s. Firms speculated that the plants could be covered by Utility Patents immediately after the Chakravarty case in 1980. A number of firms sent applications to the patent office in the early 1980s. The ex Parte Hibbard ruling officially gave firms the ability to patent plants for the first time in 1985. At the same time the use of trade secrets to protect inbreds to be used to produce hybrid corn was validated in the courts for the first time in the 1987. (Pioneer Hi-bred Int'l v. Holden Foundation Seeds, Inc. No. 81-60-E, slip op. (S.D. Iowa, Oct.29, 1987)).

C. Proposed Changes

The top priority of the American Seed Trade Association (ASTA) is to eliminate the current farmers' exemption in PVPA. ASTA members are not opposed to farmers saving their own seed, but they do oppose the farmer's right to sell seed. The other change currently under consideration is to amend PVPA so that it conforms with the 1991 UPOV Convention. Varieties that are "essentially derived" from a protected variety would also be owned by the breeder of the protected variety. Depending on how essentially derived is defined, acceptance of this provision could reduce the scope of the research exemption and increase appropriability considerably. A series of committees within ASTA is working to develop an acceptable definition of "essential derived."

The most likely changes in U.S. utility patent legislation are changes that would bring the U.S. in line with the rest of the world. Specifically, the rule on priority of patent claims might change from "first to invent" to "first to file" which is the rule in most of the rest of the world. This would reduce patent litigation in the U.S. because much litigation centers on who and when a new product or process was invented.

At a recent meeting in Washington[4] some public sector scientists have suggested that plants should not be subject to patents or that there should be a research exemption in the utility patents for plants. However, little support was expressed for this position by representatives of the private sector. Those who supported this position seem to have been in the minority.

IV. Previous Evidence of Impact of IPRs

Two surveys of seed companies were conducted in the early

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[4]. Meeting on "Intellectual Property Rights: Protection of Plant Material" was sponsored by the Crop Science Society of America, the American Society of Horticultural Science, and American Society of Agronomy and the Soil Science Society of America. 26-28 January 1993, Washington, DC.

1980s to answer the question of the impact of PVPA (Perrin et.al.1983 & Butler and Marion 1985). Figure 1 shows R&D expenditure divided by the value of the crop which holds demand constant in order to show the impact of appropriability. As expected, the ratios of self pollinated crops like wheat and soybeans increased about the time PVPA was passed. In addition crops in which hybrid seeds are widely used such as maize and sorghum have higher research: value ratios than self pollinated crops. This is due to property rights in the form of trade secrets and greater demand for the seed of these crops because hybrids can not be reproduced by farmers. Both Perrin et al and Butler and Marion conclude that PVPA had a positive effect on private plant breeding for small grains and soybeans, but were puzzled why small grains breeding increased before the PVPA was passed 1970.

Recent research indicates that the increase in small grains research documented in Figure 1 was only partially due to PVPA. Most of the research on small grains was on wheat. The history of hybrid wheat by Knudson (1990) indicates that most wheat breeding in the 1960s and 1970s was undertaken with the expectation that hybrid wheat would be successful. As firms gave up on hybrid wheat they tried to market improved wheat varieties protected by PVPA. When they could not make profits on varieties most firms stopped breeding hard red wheat entirely. Thus, the increase in cereals R&D was largely due to the expectation of increased appropriability due to hybrids rather than PVPA.

There have been no empirical studies of the impact of utility patents on plant breeding. In 1987 OTA surveyed 39 seed firms, biotechnology firms, universities and USDA about their views on the different types of IPRs. On the basis of this survey OTA concluded that utility patents were important in stimulating biotechnology firms to do research on plants (OTA 1989:85), but less important for the other types of firms or the public sector.

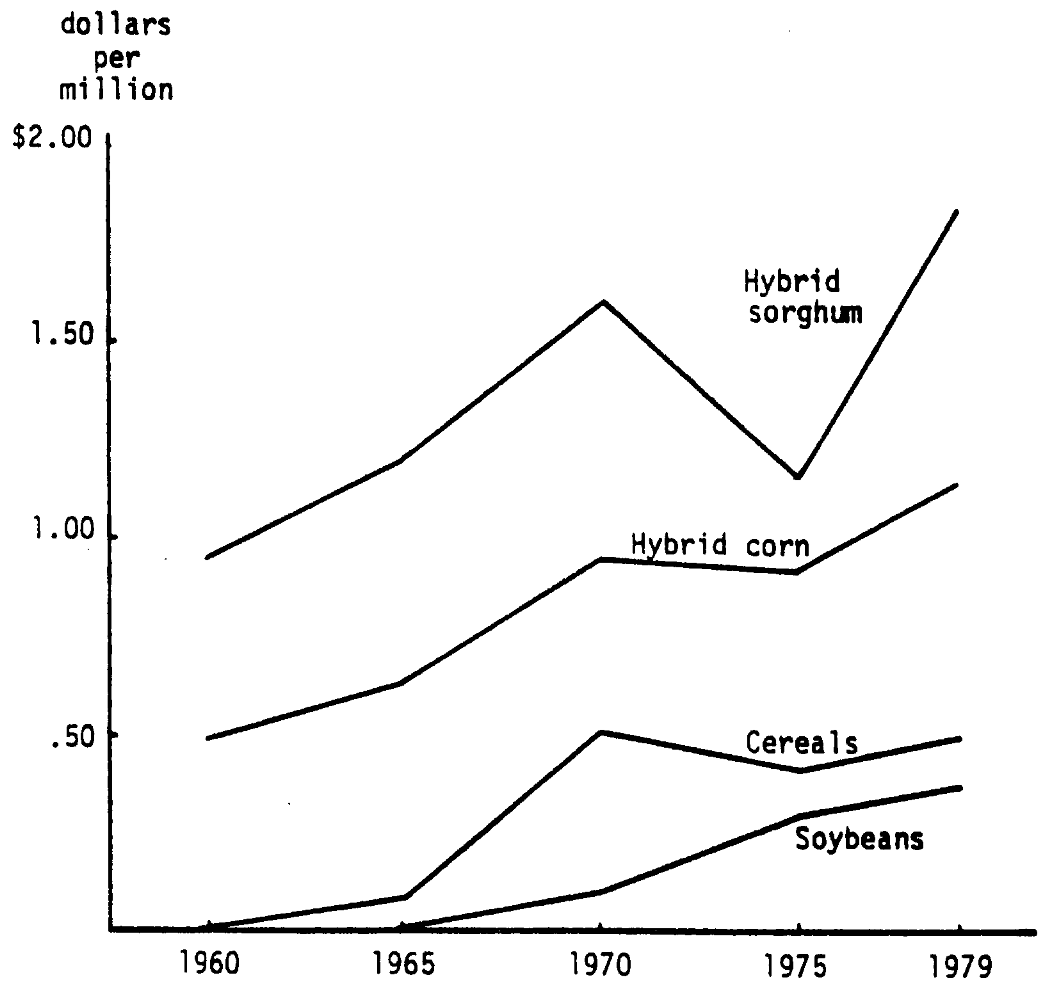


Figure 1. Crop Breeding Research Expenditures (59 Firms) Per Million Dollars of Annual U.S. Crop Value in the Preceding Five Years.

V. Empirical Evidence on Impact of IPRs

A. Survey of Private Research

To measure the impact of IPRs on private research since 1980 we conducted a survey similar to the one conducted by Perrin et al (1983). The first part of the survey requested R&D expenditures and sales by crop. The second part asked about the impact of PVPA and utility patents on profits, R&D, spillovers from public to private research and spillovers between private firms. The survey was sent to 564 companies who were active members of the American Seed Trade Association as of March 1, 1991. An additional 90 surveys were sent out to non-ASTA members. In total 654 firms were sent questionnaires and 237 responded. 121 stated that they did not have plant breeding programs. 90 of the responses were from firms with plant breeding programs who completed the entire questionnaire. 5 firms with breeding programs chose not to provide sales and R&D data, but completed the second part of the survey. 4 of the surveys were returned with a note that the firm had undergone a merger or acquisition and 17 of the surveys were classified as undeliverable.

In 1990 the 84 participating firms reported seed sales of approximately $ 1.8 billion and R&D of $137 million (Table 2). R&D as a percentage of sales (research intensity) was around 8 per cent. This is larger than the 59 firms that replied to the Perrin et al. survey. It is less than the 157 firms that replied to a short questionnaire sent out by three private sector scientists (Kalton, Richardson and Frey 1989. That survey asked only about number of scientists, broad classes of R&D expenditure and no information on sales. Kalton et al do make a rough estimate of total R&D expenditure in 1989 of $272 million. If Kalton et al are correct, our study includes about half of the private seed research conducted in the U.S. The share of R&D of different crops is similar to Kalton except for wheat and other cereals which appear to be underrepresented in out survey. The information on PVPCs (below Table 4) suggests this sample underestimates wheat and soybeans.

Table 2. Sales, R&D and IPRs for Participating Firms by Crop in 1990.

Crop	#firms	Sales ($ millions)	R&D ($ millions)	R&D/Sales	PVPCs	UPs
Hybrid Corn	42	1008	67	.07	133	25
Hybrid Sorghum	9	30	4	.13	4	0
Soybeans	23	208	16	.08	105	2
Vegetables	20	214	24	.11	252	4
Forage	12	111	7	.06	45	0
Wheat	7	35	4	.11	20	1
Cotton	5	2	1	.65	11	0
Grasses	9	102	2	.02	94	0
Other[1]	21	50	12	.24	55	4
Total	84	1761	137	.08	719	36

Source: Survey.
1 Includes crops for which the number of respondents was less than five.

B. Impact of IPRs on R&D

This section first examines trends in the determinants of R&D. These trends are broken down by crop when possible. Then it looks at the trends in R&D and R&D divided by sales for the main crops.

1. IPRs and Other Factors that Influence Appropriability

Tables 3, 4, and 5 show the use of Plant Patents, PVPA and utility patents for all firms not just those in our survey. Plant patents continue to be extensively used for asexually propagated flower and fruit varieties (Table 3). Table 4 shows the number plant variety certificates. Figure 2 shows the PVPCs of the four most important field crops which are held by the private sector. One of the most significant changes between the 1970s and the 1980s is increase in certificates for corn varieties. Table 5 shows the distribution of the utility patents issued in 1985 through 1988. In contrast to PVPCs the most utility patents were issued for two crops in which the commercial seed is primarily F1 hybrids - corn and sunflowers.

Table 3. Plant Patents Issued.						
	Number granted between					
Crop[5]	1931-62	1963-68	1969-73	1974-78	1979-83	1984-87
African violet	9	0	12	45	54	49
Almond	6	15	9	11	15	7
Apple	55	22	17	36	33	17
Azalea	49	40	34	27	7	4
Begonia	4	0	7	28	7	4
Camellia	38	5	4	1	0	1
Carnation	50	6	11	33	10	83
Chrysan-themum	133	38	68	155	99	128
Fuchsia	27	3	0	0	0	1
Gladiolus	30	53	8	6	0	0
Grape	10	8	5	9	16	14
Kalanchoe	0	0	5	33	14	30
Nectarine	59	14	25	29	17	23
Peach	151	29	29	30	34	30
Plum	25	18	6	16	14	31
Poinsettia	13	14	17	22	0	15
Rose	1,061	232	141	239	232	201
Strawberry	30	8	13	18	21	14
Annual average	53	108	111	189	162	227
Total	2,207	647	556	946	808	907

Sources: American Association of Nurserymen, Plant Patents with Common Names, 1931-1962; 1963-1968; 1969-1973; 1974-1978 (Washington, DC: American Association of Nurserymen, 1963; 1969; 1974; 1981).

[5]Partial listing of most common plants, representing from 70 to 79 percent of plant patents for the time period.

Table 4. Number of Certificates in Force Dec.31,1990 by Crop

Soybean	486	Fescue	90
Wheat	234	Ryegrass	86
Pea	195	Lettuce	85
Cotton	176	Alfalfa	71
Corn	162	Barley	42
Garden Beans	139	Bluegrass	40

Source: USDA Plant Variety Protection Office Official Journal Vol. 18, December 1990.

Table 5. Number of Utility Patents Issued for Plants by Crop

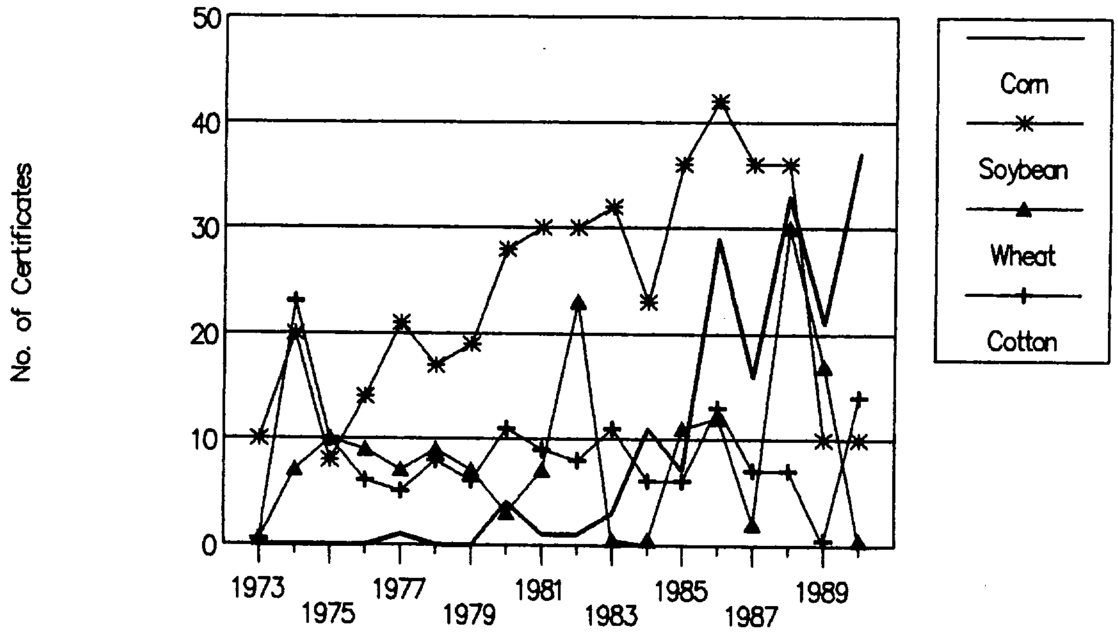
Corn	11
Sunflowers	6
Soybeans	5
Wheat	5
Others	17
Total	42

Source: OTA 1989.

Most firms in our sample believed it was in their interest to use PVPA. 51 firms held at least one PVPC. Only 11 firms held a utility patent on a plant or plant part. To find out more about firms' perception of PVPA and UPs, the survey included questions about the impact of intellectual property rights on R&D, profitability and on spillover. Firms perception of the impact of PVPA and UPs is shown in Table 6. Firms were asked to rate the impact of PVPA and UPs on types of spillovers and on profits from plant breeding on a scale from -3 to 3. The table below reports both the mean score and the number of firms that rate the impact as positive, negative or none.

PVPA appears to have increased the flows of information and perhaps germplasm from government R&D and from other private firms. Of the firms that thought PVPA did have an impact 25

Figure 2. No. of PVPCs of Wheat, Soybean, Cotton & Corn



thought the impact on information from the government was positive and only 9 thought it was negative. Regarding information from other firms, 34 thought PVPA had a positive impact compared to 17 that thought the impact was negative. Firms were about evenly divided about the impact on germplasm movement.

In contrast, utility patents may have decreased the spillover of germplasm while they were neutral on information exchange. 30 firms (38%) felt that the effect of utility patents on exchange with the public sector was negative, 14 thought it was positive, and 36 felt there was no impact. This finding is quite worrying, although as the public sector becomes more familiar with patents this may become less of a problem. Regarding spillovers within the private sector, 28 firms (35%) felt that UPs limited germplasm exchange between private companies, 17 felt this effect to be positive, and 35 reported that there was no impact.

If IPR's positive impact on a firms' ability to appropriate the gains from research outweighed the negative impact of reduced spillovers, firms profits from R&D should increase and R&D should increase. 67 firms reported that the PVPA increased their ability to profit from breeding new varieties, while 24 reported that it had no impact and only one reported a perceived negative impact on profitability. Firms were less sure about the impacts of utility patents - 43 said utility patents increased profitability, while 8 reported a negative impact.

Since there is data to analyze the impact of PVPA on breeding but it may be too early to estimate the impact of the Hibberd ruling of 1985 which permitted UPs on plants, the survey asked firms about the impact of UPs on research. Firms reported that the extension of utility patent protection to plants had little effect on breeding efforts. Only 6 reported that the availability of utility patent protection increased their research expenditures and one more commented that they had increased research before 1985 in anticipation of the ruling. Eight firms reported a decrease in R&D, with 76 firms reporting no change total expenditures. In addition 14 firms reported that research priorities changed after 1985 due to the availability of UPs.

Table 6. Impact of PVPA and Patents on R&D Number of Firms

	Impact of PVPA				Impact of UPs			
	Mean	+	No	-	Mean	+	No	-
Info from Govt. R&D	.27	25	58	9	-.18	15	46	19
Germplasm from Govt. R&D	.18	24	49	19	-.16	14	36	30
Info from Other Firms	.08	34	41	17	-.51	20	40	20
Germplasm from other firms	.08	24	49	19	-.33	17	35	28
Ability to Profit	1.43	67	24	1	.89	43	31	8
More or Less R&D due to ex parte Hibbard						6	69	0

Source: Survey

Firms' perception of increased profits from breeding due to PVPA and utility patents seems to outweigh their concern about reduced spillovers. Even for utility patents only 8 firms stated that the profits will go down despite the fact that 30 thought there was less spillovers from the government and 28 thought there was less spillover form other private firms.

Intellectual property rights for hybrids increasing during the 1980s due to ex parte Hibbard and the court ruling on trade secrets. Property rights in some self pollinated crops such as wheat and cotton in some areas were declining because of the ease with which farmers could reproduce seed and court rulings that specified the extent of the farmers right to sell seed. Thus, R&D and R&D/sales should be increasing in hybrids and declining in some self pollinated crops.

Different types of seed firms may have quite different research expenditure patterns due to different levels of appropriability that they face. Table 7 shows the different levels of R&D and R&D/sales for several different types of seed firms. These differences could be due to the structure of the industry -

vegetable varieties may be easier to control because there are a small number of seed companies and a small number of growers (Foster and Perrin 1990). Their research expenditure may also be different at different stages in the life cycle of the firms. When the firm is just starting up, it will invest money in research but have little or no sales. Finally, certain types of firms are primarily research firms. Foundation seed companies will have very high research intensity because they have low seeds sales and some of their research is essentially contract research for other firms.

2. Changes in Technological Opportunity and Demand

In addition to the changes in intellectual property rights the other major variable that changed since 1980 was technology opportunity due to advances in molecular biology. Many firms and government institutions have applied biotechnology techniques such tissue culture and genetic mapping to plant breeding in the mid 1980s. Using these techniques they are improving the efficiency of plant breeding and producing varieties resistant to pests and herbicides. The public and private sectors are also working on transgenic plants some 300+ of which are in field trials. So far no transgenic crop varieties are available commercially.

The extent of biotechnologies impact on private plant breeding is indicated by the 1989 study by Kalton et al. They found 252 PhDs working on biotechnology related to plant breeding compared to 580 PhDs working on conventional breeding. The pattern of biotechnology research by seed firms is shown in Table 8. Corn biotechnology attracted three times the research resources of any other individual crops and twice as much resources as all vegetables together. This pattern reflects the size of the market for various types of seed and firms' perception of intellectual property as well as differences in technological opportunity between crops.

The other factor that our model suggests would influence R&D is demand for seed. Firms should do more research in crops which have rising seed prices and quantity demanded is rising. Table 9 shows the value of seeds planted and Figure 3 the trends in seed prices and quantity demanded of the major crops. Corn was by far the most important crop in terms of value of sales and it also led in growth of value between 1974 and the present. Figure 3 shows that the value of seeds sold of corn, sorghum and soybeans grew rapidly between 1974 and 1985 and then declined or levelled off. The value of cotton seed sale grew until 1981 and then declined. Wheat is only one of these crops that declined in the 1970s and 1980s and ended with its value in nominal dollars in 1990 lower than in 1974.

Table 7. Sales, R&D, and IPR's by Type of Firm for 1990.

Type	# Firms	Sales	R&D	R&D/Sales	PVPCs	Patents
		(Million $)				
Field Crops						
Vertically[6] Integrated	4	972.6	52.9	.05	183	15
Regional[7]	30	317.5	22.3	.07	67	2
Foundation[8] & Start-ups[9]	30	132.4	37.2	.28	74	18
Sub-Total	65	1387.5	105.4	.08	324	35
Other Crops[10]						
Vegetables	17	210.1	19.9	.09	207	1
Flowers & Grasses	9	128.5	4.8	.04	133	0
Sub-Total	26	338.6	24.7	.07	340	1
Total	91	1726.1	130.1	.08	664	36

Source: Survey

[6]Firms that specialize in field crops and had seed sales greater than $50 million a year in 1990.

[7]Firms that specialize in field crops and had seed sales less than $50 million a year in 1990.

[8]Firms that specialize in the production of foundation seed.

[9]Firms that were established or entered the seed business after 1980.

[10]Firms that specialized in the production of the following groups of crops. A few start-up companies are included in these categories.

Table 8 Number of Companies and Scientist Involved in Biotechnology Research Related to Plant Breeding

Crop	Companies	PhD	Other Scientist & Technicians
Corn	19	90.1	168.2
Vegetables	17	31.4	90.6
Soybeans	6	17.3	29.0
Cotton	5	7.15	16.8
Sugar beets	3	6.5	9.0
Canola	3	9.5	27.0
Alfalfa	2	2.1	10.4
Sunflower	2	1.0	6.0
Wheat	2	1.1	2.3
Other small grains	1	.5	1
Rice	1	.25	0
Turf grasses	1	0	.9
Forage grasses	1	0	.1
Undifferentiated by crop	2	85.0	55.0
Total		251.9	411.8

Source: Kalton, Richardson and Frey 1989.

3. Trends in R&D

During the 1980s one would expect corn R&D to grow the most rapidly of the five main crops because IPRs of corn and sorghum were strengthen the most, the value of seed grew the most and the most biotechnology R&D was conducted on corn. Wheat should do the worst in the 1980s because IPRs were weakened, hybrid wheat turned out to be commercially impractical, and the value of wheat seed purchased by farmers declined. R&D by the other three crops should be somewhere in between possibly led by sorghum, then soybeans and cotton.

Table 10 shows that hybrid corn accounted for the largest share of total R&D in 1990, followed by the class of vegetable crops, soybeans, forage crops, hybrid sorghum and wheat. Hybrid corn was also the individual crop for which firms held the most Plant Variety Protection Certificates (PVPCs) and was again

Table 9. Quantity, Price and Sales of Seed of Five Crops

	Tons Planted (1,000s)	Price per ton $s	Value of Seed Planted Million $s	Percent Purchased	Value of Seed Purchased Million $s
			1985		
Corn	493.64	2872.00	1417.73	95.00	1346.84
Wheat	2348.22	227.70	534.69	35.00	187.14
Soybeans	1623.34	444.30	721.25	60.00	432.75
Cotton	119.25	1079.68	128.75	50.00	64.38
Sorghum	63.02	1480.64	93.31	95.00	88.64
			1991		
Corn	439.46	3276.00	1439.67	95.00	1367.68
Wheat	2401.82	216.72	520.52	35.00	182.18
Soybeans	1486.29	477.87	710.25	60.00	426.15
Cotton	138.39	1303.68	180.42	50.00	90.21
Sorghum	36.19	1594.88	57.71	95.00	54.83

Sources: Area planted, seed rate and price from USDA _ Agricultural Statistics 1991 Washington:GPO 1991. Percent purchased from Butler and Marion 1985.

followed by soybeans. Firms held 252 certificates for vegetables, which is nearly equal to the total for the major grain crops. Thus, PVPCs were primarily used to protect innovations in corn, vegetables, and soybeans. Two-thirds of the utility patents were used to protect corn varieties or characteristics. The rest were scattered among a number of crops.

Seed research in total has grown rapidly since 1979 or 1980 (Table 10). Perrin's estimate of $54 million (1982 $s) for 1979 R&D is probably closer to the industry total than our estimate of $35 million (1982 $s) for 1980.[11] Using either estimate real research expenditure in some crops grew very rapidly. Corn research grew rapidly as expected - at least doubling in real terms. Cereals which includes wheat declined as expected.

[11]. Firms that went out of business between 1980 and 1990 would not have been included in our sample. 1980 research by firms that merged may also not have been reported by the new firm. Also some firms who report having R&D programs in 1980 only provide R&D data for 1990 and/or 1985.

Figure 3 Indices of Seed Sales

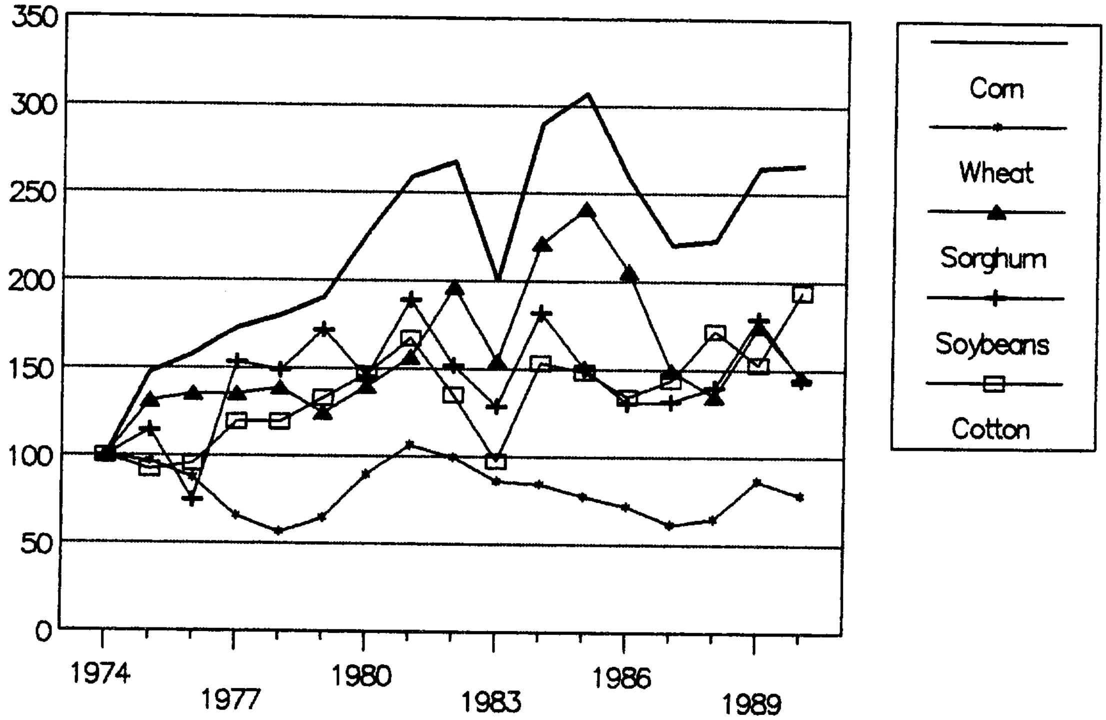


Table 10. R&D Expenditures by Crop, 1979-1990.[1]

Crop		(Thousands of 1982 dollars) 1979[2]	1980	1985	1990
Hybrid Corn	R&D	25121	21544	35029	51249
	R&D/Sales	.038	.033	.056	.067
		(32)	(26)	(32)	(42)
Hybrid Sorghum	R&D	3622	1902	2513	3095
	R&D/Sales	.043	.078	.073	.133
		(18)	(5)	(7)	(9)
Soybeans	R&D	5465	3060	5676	12435
	R&D/Sales	.041	.052	.051	.078
		(21)	(14)	(18)	(23)
Cereals	R&D	9564	1204	3485	4241
	R&D/Sales	.208	.276	.255	.139
		(9)	(1)	(4)	(11)
Vegetables	R&D	5506	3110	6811	17956
	R&D/Sales	.048	.055	.104	.110
		(16)	(7)	(15)	(20)
Forage and turfgrasses	R&D	3879	3727	4563	6537
	R&D/Sales	.017	.036	.037	.040
		(16)	(10)	(15)	(19)
Other	R&D	1117	893	3669	6708
	R&D/Sales	.010	.120	.188	.236
		(11)	(5)	(11)	(16)
Total	R&D	54274	35440	61746	102221
	R&D/Sales	.038	.041	.063	.078
		(59)	(43)	(63)	(84)

Source: 1980 - 1990 Survey.
1979 Perrin, et.al., "Some Effects of the U.S. Plant Variety Protection Act of 1970," Economic Research Report No. 46 (Raleigh, North Carolina: Dept. of Economics and Business, North Carolina State University, 1983) p. 25.

[1] Numbers in parentheses are the number of firms with active plant breeding programs.

Soybean research between 1979 and 1990 grew 228 percent, which was more than corn and more than expected. Sorghum did not grow much. R&D on vegetable grew by 326 percent.

B.2. Regression analysis

Regression analysis was used to try to sort out the relative influence of these different factors on private R&D. Two dependent variables were used. First, R&D by firm was regressed on demand, IPR variables, spillover variables and characteristics of the firms. Second, R&D by crop and firm was regressed on the public R&D by crop, IPR variables and industry demand variables. The results are shown in Table 11.

None of the industry demand variables, such as growth in value of sales of seeds by crop in the previous five years, were significant. Public sector plant breeding R&D by crop of five major crops from 1972 to 1988 from USDA CRIS was also insignificant in all specifications.

The sales variables is consistently positive and sales squared is negative in different specifications and with both the firm and crop R&D as dependent variables. This indicates the inverted U type relationship between research intensity and size of firm found in the early empirical tests of the Schumpeterian theory. Hybrids are positive and significant at the ten percent level in the crop R&D equations. When hybrids are used as a dummy variable in the firm R&D equations, they are negative but insignificant. In the firm R&D analysis specification 3 they are positive and significant in interaction with sales. The positive sign on the interaction term seems plausible because larger firms make more money from hybrids because they have the legal departments or the resources to hire the lawyers needed to enforce trade secrets and apply for and enforce utility patents.

Various dummies were used to try to capture the impact of utility patents with mixed results. In both data sets the dummy for 1985 and 1990 was positive and significant at the 5 or 10 percent level which provides some support for the hypothesis that utility patents increased R&D. The impact of utility patents was also estimated by the using the firms' responses on the questionnaire on whether they though UPs increased their profits from plant breeding. The firms that thought UPs increased profits had higher levels of R&D than other firms using both firm and crop R&D. In the third specification in Table 11 the time dummies were 1 for 1980 and 1 for 1985. Thus, they were expected to have a negative effect if firms were gradually convinced of the increased importance of utility patents. In interaction with sales they do have a negative and significant impact on R&D which implies that the slope of the sales variable is higher in the later years after utility patents became an accepted tool for increasing appropriability.

Table 11. OLS Regression Analysis of Firm R&D Data

	R&D Expenditure by Firm			R&D Expenditure by Crop	
Constant	-398.7	-1154.3	138.1	-277.8	-280.5
Sales	.078 (.006)	.073 (.009)	.046 (.011)	0.069 (0.005)	0.068 (0.005)
$Sales^2$	-1.02E-07 (1.0E-08)	-9.6E-08 (2.0E-08)	-1.62E-07 (1.0E-08)	-9.46E-08 (1.2E-08)	-9.4E-08 (-1.2E-08)
Hybrids	-2.08 (185.9)	-308.7 (229)	-580.1 (185.8)	319.65 (168.1)	347.37 (167.5)
D85-90	455.1 (208.7)	418.9 (206.6)		295.15 (176.1)	
Exp.Profits from UPs	339.6 (181.3)	334.3 (181.9)	524.4 (160.9)		160.27 (80.15)
Integrated Firms		1861 (729)			
Regional Firms		857 (375)			
Foundation Seed Firms		2223 (569)			
Start up Firms		1104 (380)			
Vegetable Seed firms		881 (379)			
Flower seed Firms		890 (593)			
HYB*Sales			.068 (.012)		
1980*Sales			-.026 (.003)		
1985*Sales			-.014 (.004)		
R Squared	.75	.774	.813	.649	.657

The dummies for some types of firms shown in Table 7 were significant. Foundation seed firms and the large integrated firms had to largest increases in R&D over grass seed firms which were represented by 0. They were significant at the 5 percent level as were the other industry dummies except flower seed.

The regression indicates that some of variables used to represent utility patents and firms perceptions of utility patents did have a positive impact on R&D. Firm size has a positive impact and certain types of firms - foundation seed firms and large integrated firms - also had a positive impact. However, several other variables which we believe affect R&D - public R&D and growth in demand - did not have significant impacts probably due to the fact that they were crop level variables rather than firm level variables.

Conclusions

The data on private research suggests that private firms and were induced to conduct more research on the crops in which intellectual property rights were strengthened most. PVPA did not, however, cause as much increase in R&D as earlier studies suggested because they had neglected to correct for the firms' mistaken belief that hybrid wheat would be profitable. Firms did not find that germplasm exchange or information was reduced by PVPA.

About 38% of the firms surveyed felt UPs hampered their exchange of germplasm with the public sector and 35% said it reduced the exchange of germplasm between firms. This problem may decline as firms and universities get more experience with UPs, but at the moment there does appear to be a decline in information and germplasm exchange. However, over half of the firms indicated that UPs would increase the profitability of plant breeding while less than 10 percent thought the impact would be negative. This suggests that overall the firms felt utility patents were a good thing.

The trends in R&D expenditure by crop were generally consistent with trends in IPRs, demand and technological opportunity. Corn research grew rapidly as expected - at least doubling in real terms. Cereals which includes wheat declined as expected. Soybean research between 1979 and 1990 grew 228 percent, which was more than corn and more than expected. Sorghum did not grow.

The regression analysis suggests that UPs did stimulate research by seed firms as well as by new biotechnology firms. Those firms that stated UPs had increased profits from breeding did do more R&D than those who thought it was neutral. Other dummies such as time and hybrid dummies also indicate the stronger property rights lead to more R&D.

In conclusion, it appears that stronger intellectual property rights in the form of utility patents and trade secrets have increased the amount of R&D in the U.S. despite the concerns about declining spillovers. In addition firms confirmed the findings of earlier studies that PVPA did have a positive impact on profits from R&D on plant breeding. These findings provide preliminary evidence that the strengthening property rights further through measures such as eliminating farmers rights to sell seed and adopting UPOVs convention on essentially derived varieties would increase R&D. More study is needed to answer the question of the impact of more private R&D on farmers.

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