THE CHANGING AGRICULTURAL RESEARCH ENVIRONMENT: WHAT DOES IT MEAN FOR PUBLIC-PRIVATE INNOVATION?

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Agricultural research has experienced increased industry spending and public-private collaborations. Private incentives for public goods research are limited. Public-private ventures can foster socially beneficial research. Joint research opportunities must attract firms, yet conform to public goals. A strong public research sector can allay concerns about industry's role in research and development (R&D).

Key words: agriculture; biotechnology; Cooperative Research and Development Agreement (CRADA); intellectual property rights (IPRs); public policy; research and development

The agricultural research system has undergone significant changes during the past years. Increased private sector investments in agricultural R&D have been accompanied by recent consolidation of chemical, seed, and biotechnology companies. Private sector agricultural R&D efforts have expanded, motivated primarily by advances in biotechnology, strengthened intellectual property rights, globalization of markets, and new opportunities to collaborate with public research institutions. At the same time, the public sector has promoted collaborations with the private sector mainly to transfer technologies to the marketplace. Collaborations with the private sector have also served to supplement limited public R&D resources. These events have raised concern about the supply and focus of agricultural R&D in the private and public sectors.

The Changing Research Environment

One critical change in the agricultural research arena has been advances in biotechnology, which created new technological opportunities. Biotechnology methods, such as tissue cell culture and genetic engineering, have made it possible for researchers to reduce the time to improve plant varieties, as well as increase their precision in modifying plant traits. Therefore, developing new crop varieties with production- or quality-enhancing traits is profitable for the agricultural input industry. Many of these crops have capitalized on new linkages between seed and chemical inputs. New herbicide-resistant crops complement established herbicide product lines and boost sales by expanding the number of crops resistant to the specific product lines. The development of insect-resistant crops enables seed and chemical companies to offer new crop protection technologies.

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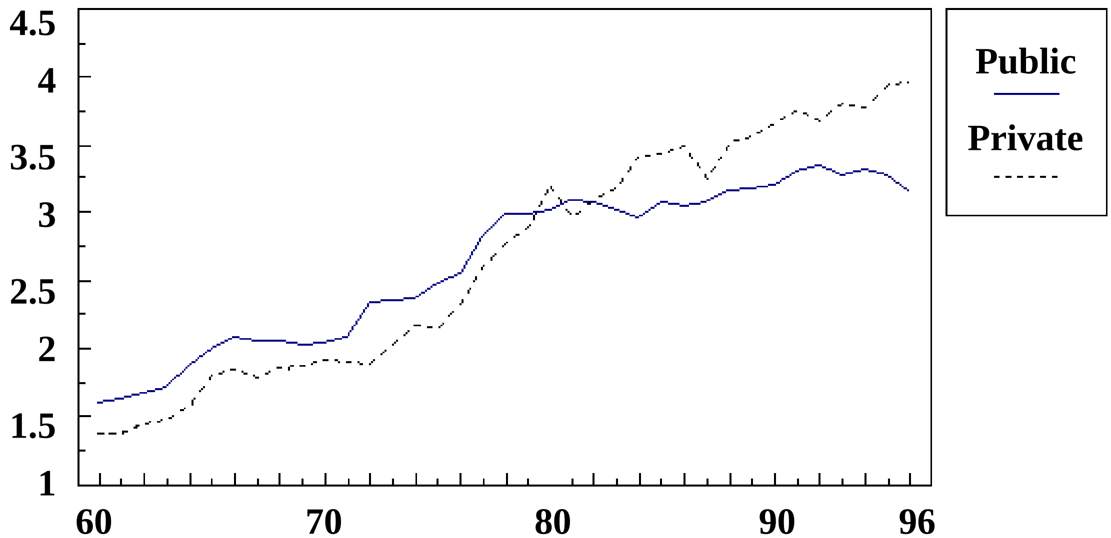
Expanded IPRs for biological inventions have stimulated private sector plant breeding efforts over the past 25 years. In 1970, the United States (U.S.) Congress instituted the Plant Variety Protection Act (PVPA) which awarded plant breeders' rights for new crop varieties produced from seed, particularly field crops. Since then, the PVPA has been revised to expand coverage to vegetables and tubers, to restrict farmers' rights to resell protected seed, and to disallow protection for new varieties that simply involved superficial changes in appearance. Utility patents were first granted for biological inventions by the U.S. Patent and Trademark Office in 1980, when the Supreme Court authorized the use of standard Utility patents for microorganisms. Utility patents were authorized for plants and animals in 1985 and 1987, respectively. Evidence suggests that these decisions have promoted private sector plant breeding activities. Private sector R&D efforts in plant breeding, measured in scientist years, have intensified and are now slightly more than twice the plant breeding effort in the public sector (Frey, 1996). Moreover, the private sector owns the majority of total PVP certificates and Utility patents awarded for multicellular living organisms (Fuglie *et al*., 1996).

Globalization of agricultural input markets and falling barriers to trade have provided opportunities for private industry to expand sales and increase research efforts in other countries. Pray and Fuglie (in press) find increasing global markets for agricultural inputs as evidenced by the 2.23 percent real annual growth in U.S. exports of these inputs since 1983. Foreign market and investment opportunities have also been broadened by trade agreements, such as the General Agreements on Tariff and Trade (GATT), the World Trade Organization (WTO) and the North American Free Trade Agreement (NAFTA). The number of foreign-owned patents for agricultural technologies and research investments by multinational firms have been expanding in many countries (Pray & Fuglie, in press).

Another change affecting technology development has been the growth of collaborations between the public and private sectors. Before 1980, collaboration was limited because the private sector could not assume ownership of any inventions that resulted from federally-funded research. The government patent policy of 1980 (Bayh-Dole Act) granted all institutions "certainty of title" for inventions resulting from federally funded research. The Bayh-Dole Act also allowed federal laboratories to issue exclusive licenses for patents of their inventions, which are more attractive than the nonexclusive or open licenses previously granted to firms. Other legislation sought to promote greater collaboration and exchange between federal laboratories and the private sector. The 1980 Stevenson-Wydler Technology Innovation Act mandated that each federal research agency develop specific mechanisms for disseminating government innovations. The 1986 Technology Transfer Act gave government agencies additional means to foster technology transfer by authorizing Cooperative Research and Development Agreements (CRADAs). Previously, federal researchers were not permitted to collaborate directly with the private sector (Congressional Research Service, 1991). The United States Department of Agriculture's collaborations with the private sector have significantly increased over the last decade (Day-Rubenstein & Fuglie, in press).

The events summarized above have contributed to increased private sector involvement in agricultural R&D. Private investments in agricultural and food R&D have nearly tripled in real terms (figure 1), from about $1.3 billion in 1960 to $4 billion in 1996 (Fuglie *et al*., 1996).

Figure 1. Public and Private Agricultural Research, 1960-1996 (billions of 1996 dollars)



Private agricultural research investments have exceeded public sector spending since the early 1980's. Public sector expenditures in 1996 were $3.15 billion, about $800 million less than private sector expenditures. The composition of private sector research has also changed. The share of R&D expenditures for biological and chemical inputs (plant breeding, agricultural chemicals, and veterinary pharmaceuticals) rose from 19 percent of total agricultural research spending by private firms in 1960 to 58 percent in 1996. Furthermore, private support of public sector research funds has become increasingly important. The non-governmental share of funding (industry grants, product sales, and other sources combined) had the most rapid rate of growth. Between 1978 and 1996, this funding source increased from 14 percent to 20 percent of total research expenditures at state agricultural research institutions. Research grants from industry grew from 5.1 percent to 7.5 percent during this period.

Finally, mergers, acquisitions, and strategic alliances in the agricultural input industry have increased substantially in recent years, leading to consolidation in the agricultural input industry. Major agricultural chemical companies have been acquiring or entering strategic alliances with seed and biotechnology companies in order to take advantage of new linkages between seed and chemical inputs. These changes have allowed companies to expand access to seed markets, enabling technologies, and patent portfolios (see *AgBioForum*, Vol.1 No. 2).

Concerns About The Changing Research Environment And The Supply Of Innovation

Questions have been raised about whether increased private sector efforts in agricultural research would promote the development of technology that provides the most benefits to society. One concern is that increased private support of public research could unduly influence the public R&D agenda. Specifically, public research programs could be disproportionately leveraged toward the needs of private industry, rather than for the broader interests of farmers or consumers.

For instance, a firm could give a grant to a university department to conduct specified research. The university, in turn, may not charge the firm the full cost of doing the research because its buildings, equipment, and staff are considered a "sunk cost." In a study of barley research in Canada, Ulrich, Furtan and Schmitz (1986) found that when brewing and malting companies increased their financial support of public barley research, greater weight was given to improving malting quality rather than increasing yields. Higher yielding varieties would have been more beneficial to livestock producers according to the study. The study concluded that while both the public and private sectors gained from the joint research effort, the social cost of private assistance was high.

Joint ventures between the private sector and universities are becoming more numerous. One recent example of this is an experimental agreement between Novartis Agricultural Discovery Institute, Incorporated and the University of California at Berkeley (University of California, 1998). Novartis will provide Berkeley with $25 million over five years for basic research in agricultural genomics, as well as provide access to DNA (deoxyribonucleic acid) databases and proprietary technology. The University will own the patents and earn royalties from any discoveries made under the contract. In return, Novartis will have first rights to license about 30-40 percent of any inventions made in the Department of Plant and Microbial Biology. The question under such university-industry arrangements is whether they could result in the suppression of research results leading to less dissemination of public research. While joint ventures provide university researchers with access to much needed private sector resources and research, they may also limit access to innovations in the public sector thereby potentially hindering technological progress.

Another frequently cited concern is the potential for firms to gain too much market power through consolidation and greater appropriability of research awarded by IPRs. These firms generally have greater access to capital and markets than smaller, startup technology firms for example (Barton, 1998). This could inhibit technological progress by creating barriers to entry for new firms. Furthermore, strengthened IPRs may reduce access to innovations, limiting private and public sector development of potentially important technologies. However, firms with extensive IPRs are often in a better position to capture the economic gains from research investments and, therefore, will have greater incentive to provide technologies that enhance crop yields and reduce costs for agricultural producers. Some of these benefits may be transferred to consumers through lower prices. Hybrid seed technology illustrates this point. The private sector is able to appropriate more of the gains from hybrid research efforts since the yield vigor of hybrid crops decreases in subsequent growing seasons requiring farmers to repurchase seed every year. As a result, private sector research investments in hybrid crops (e.g., corn and sorghum), as a share of seed sales, were two to three times greater than research expenditures devoted to non-hybrid crops (e.g., wheat, soybeans, and cotton) (Fuglie *et al*., 1996).

Finally, since firms focus on private benefits, concerns arise that private sector research may fail to develop socially optimal technologies. One example is the plant sterility gene, often referred to as the “terminator” gene. Similar to hybrid technology, the development of these sterile plants will offer an inherent form of plant variety protection. In 1998, Delta and Pine Land Company (now owned by Monsanto) and the Agricultural Research Service (ARS) were granted a patent for this technology. It potentially could expand hybrid-like protection to crops that were not previously candidates for hybrid technology, such as cotton, wheat, rice, and soybeans. Unlike hybrids, however, second generation seeds are sterile. This technology enhances firms’ ability to capture returns on their research investments, thus, in theory, creating incentives for R&D and possible varietal improvements. This technology has been controversial because it was a collaborative effort between the public and private sector that led to the development of a technology that may not have clear benefits to farmers. In other words, critics have questioned whether the public sector should be contributing to research with strong benefits to private industry. The technology probably would not have a large impact on U.S. farmers who already repurchase a significant portion of their seed every season. However, it may affect farmers in less developed countries who rely heavily on saved seed for future plantings.

Public Research Policy Response

Public research policy can account for the increasing role of the private sector in agricultural research. In response to increased private sector activity, public research institutions have been directing more resources to research with a public goods component. While this research offers the greatest overall benefit to society, private returns are limited and industry has little incentive to conduct this research (Fuglie *et al*., 1996). One example of research with a strong public goods component is basic research. Although basic research has higher social rates of return than applied research, results generally cannot be appropriated. As a result, the share of private sector research expenditures devoted to basic research is only 16 percent, whereas 47 percent of public sector research funds are allocated to basic research (table 1).

Table 1: Shares Of Agricultural Research Expenditures.

	Percentage of Research Expenditures		
	Basic	**Applied**	**Development**
Public Institutions	46	47	7
Private Industry	15	44	42

Note. Public research data are for Fiscal Year 1997 from CRIS (1999); private research data are from a 1984 survey by the Agricultural Research Institute (1985).

Another example of public goods research is applied research addressing environmental protection and natural resource conservation, food safety and nutrition, rural development and small farms issues. Generally, these areas continue to grow in importance for the public sector. Public sector agricultural research on natural resources and the environment research grew more than 25% in real terms between 1986 and 1996. Similarly, research on microbial contamination of food increased 66% during the same period.

Differing research priorities of the public and private sector can be observed specifically in plant breeding. A recent comprehensive survey of public and private plant breeding research showed that USDA's ARS concentrates most of its research on long-term pre-breeding activities, while the private sector devotes most of its resources to short-term varietal development (Frey, 1996). The Agricultural Research Service has terminated most of its research on variety development, increasingly concentrating on research areas not pursued intensely by the private sector.

Besides ensuring that the public research agenda accounts for private sector research, the USDA has also sought to strengthen research collaborations with the private sector. Joint research with the private sector (e.g., patent licensing, research consortia, contracted research, and CRADAs) can promote the use of public sector research results, while providing additional resources for public research. The USDA often uses research collaborations to bring specific inventions to the marketplace, such as biopesticides. The USDA has established more than 700 CRADAs since the beginning of the program. Likewise, changes in patent policy have increased USDA's licensing of patents to the private sector. Royalties from patent licenses have risen steadily since 1987, indicating increased licensing activity (table 2).

A review of ARS CRADAs from 1987-1995 shows the topics addressed by this public-private research. Using USDA's classification system, CRADAs with financial data were grouped into five main areas (table 3). As expected, plant research was the largest category in terms of total resources because plants are a priority for both public and private researchers. Almost 35% of CRADA resources were used for post-harvest use research. Animal research was third among CRADA priorities.

Table 2: USDA Public-Private Research Activities.

Year	Active CRADAs[a] (Number)	Value Of CRADAs[b] ($ Millions)	Patents Awarded (Number)	Patent License Royalties ($ Millions)
1987	9	1.6	34	0.09
1988	48	8.7	28	0.10
1989	86	15.6	47	0.42
1990	104	18.9	42	0.57
1991	139	25.6	57	0.83
1992	160	30.0	56	1.0
1993	185	34.0	57	1.5
1994	212	61.3	40	1.4
1995	227	80.1	38	1.6
1996	258	98.9	53	2.1

[a] Number of CRADAs with the private sector. [b] Value of CRADAs includes the total value of USDA and private-sector resources committed to active CRADAs over their lifetime.

Table 3: Cooperative Research And Development Agreements By Resource Allocation.

	Research Categories					
Percentage of Total Resources	Natural Resources	Plant Production and Protection	Animal Production and Health	Post-harvest Use of Agriculture Commodities	Human Nutrition	General
	6.3	36.5	17.2	34.6	2.7	2.7

Note. Based on data from CRADA's initiated by ARS between 1987 and 1995. Value of research resources available for only 366 projects.

Changes in ARS research priorities during the CRADA program suggest that closer R&D cooperation between the USDA and the private sector may have enhanced research efficiency by enabling the public sector to focus resources on public goods research (Day-Rubenstein & Fuglie, in press). Overall, the pattern of research allocation by the USDA has remained relatively stable since the CRADA program began. However, USDA research resources became increasingly focused on natural resources and human nutrition, where the private sector is unlikely to develop new technology.

Public research can also foster competition among private sector research institutions. For example, public researchers can "invent around" enabling technologies held by companies. If a critical agricultural technology is protected by a patent, public researchers may work to develop new technologies that perform similar functions. For instance, USDA conducts research on apomixis traits (Adams, 1993). Apomixis allows for asexual reproduction of seeds providing a way to circumvent the hybrid barrier. Public research can also enhance competition directly by providing competing technologies. In the past, public research fostered competition in the plant breeding industry (Ruttan, 1982). One example is the hybrid corn industry. Prior to 1984, USDA released parent lines of hybrid corn varieties that benefited small companies who relied heavily on these public sector lines (Huffman & Evenson, 1993).

Concluding Comments

While there is evidence that the agricultural research environment is changing, it is not entirely clear how these changes will influence the focus and supply of innovation. Many of these changes are expected to further encourage private sector investments in agricultural research. Increased private sector participation in agricultural research will contribute beneficial technologies, such as crop varieties that can boost productivity and that have enhanced qualities. However, the private sector has little incentive to conduct public goods type research, such as natural resources, food safety, and basic research. The public sector must continue to lead these research efforts. Research policies that promote cooperative efforts between the public and private sectors, such as CRADAs, are a promising means to foster the development of technologies with greater social benefits, as well as improve the sharing of research results and resources. However, public institutions must ensure that public sector participation yields the greatest social good. Joint research opportunities must be attractive to the private sector, yet consistent with social and environmental goals. A strong public agricultural research system can allay many of the concerns about the changing role of industry R&D, as well as help maximize the benefits of increased private research contributions.

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