Chapter 3.2

Agricultural Research and Development

Margriet Caswell and Kelly Day-Rubenstein

Public and private research and development have driven impressive gains in agricultural productivity. Over the past few decades, advances in the biological sciences, as well as legislation that strengthened intellectual property protection for biological inventions, have increased research investment by the private sector. New institutional arrangements have fostered public and private collaboration in research, but it is unclear how industry consolidation and changes in public funding will affect agricultural research and its effects on productivity.

Introduction

Unprecedented growth in agricultural productivity over the past century can be attributed largely to investments in agricultural research and technology development (see Chapter 3.4, "Productivity and Output Growth in U.S. Agriculture"). Many developments—including more efficient agricultural machinery, agricultural chemicals and fertilizers, genetic improvements in crops, and changes in farm management techniques—have transformed U.S. agriculture. These developments have contributed to an abundant and affordable food supply for consumers.

Most early research efforts sought to replace increasingly expensive resources with less expensive ones. For example, the development of farm machinery helped offset increasing labor costs. Currently, demands for safer, healthier, and more convenient foods, natural resource conservation, environmental protection, and animal welfare are changing the agricultural research portfolio. These demands relate directly to agricultural products and to the impacts of production methods.

Research Demand

Many different forces affect research investment, and these forces differ for the public and private sectors. Some technology development is in response to consumer demand. This kind of focused research is often called "applied." The private sector will respond to market demands for new agricultural technologies, but markets may not address all external effects of production. Environmental regulation, for example, may increase the development of some environmentally benign technologies and the demand for those technologies.

Research can also be conducted without an immediately marketable product, usually for two reasons: basic research (to gain fundamental knowledge) and the provision of public goods. Basic research is conducted most often in the public sector because the results of the research lack immediate

Contents

private payoffs. The results, though, can provide a scientific foundation for later public and private developments. Developments in biotechnology have blurred the distinction between basic and applied research. For example, "theoretical" fields such as genomics, proteomics, and bioinformatics have been supported strongly by the private sector.

Public goods represent a market failure because an individual's use of the good does not diminish its availability to others, and it is difficult to exclude anyone from using the good. National defense exemplifies a public good because once security is provided for one, all receive the same protection. In agriculture, food safety and ecosystem stewardship have public good characteristics. While the payoff to society of investing in basic and public good research is high, the results of such research generally cannot be appropriated, so the private sector has little market incentive to conduct this research. That is where government steps in—through funding and technology transfer activities.

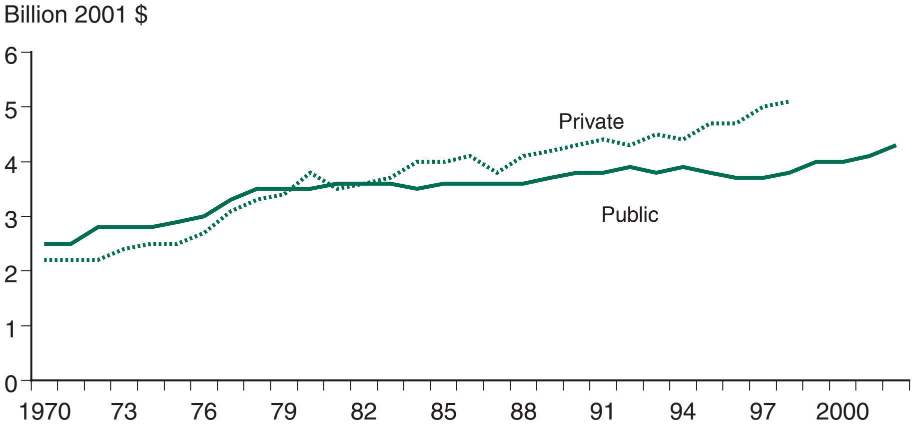
The roles of the public sector and private industry in agricultural research have undergone significant changes in the last two decades due to developments in science, policy, and markets. The public sector was the primary investor in agricultural research prior to the 1980s, but now the private sector funds the development of many new agricultural technologies (Fuglie et al., 1996; Huffman and Evenson, 2006; Klotz et al., 1995; and Pray, 1993) (see fig. 3.2.1).

Public Sector Research and Development

Public agricultural research involves a unique partnership between the Federal Government (chiefly USDA) and the States. USDA, the State Agricultural Experiment Stations (SAES), and cooperating institutions together conducted over $4 billion of research in 2002 (USDA Current Research Information System). USDA conducts much of its inhouse research through its research agencies, primarily the Agricultural Research Service, the Forest Service, and the Economic Research Service. The largest expenditures on agricultural research in the public sector are made by SAES and cooperating institutions, which rely on Federal and State funding, as well as the private sector.

Figure 3.2.1

Agricultural R&D expenditures, 1970-2002



Source: USDA, Economic Research Service.

Historically, USDA has used several funding instruments to provide research money to States. *Formula funds* are allocated in block form to States based on rural population and number of farms. Research administrators have numerous options in how they distribute formula funds. *National Research Initiative (NRI) competitive grants* are allotted by peer review panels. Special grants are awarded by Congress, whereas other USDA *contracts, grants, and cooperative agreements* are awarded at the discretion of USDA research agencies. (See Fuglie et al., 1996; and National Research Council, 1996, for descriptions and comparisons of these mechanisms.)

Within the public agricultural research sector, natural resource and environmental issues are of interest because they have both local and national dimensions. State research investments might be focused on local problems, with Federal funds designated for larger geographic issues. For example, the development of technologies to improve water quality and increase water-use efficiency can have critical local benefits (see AREI Chapters 2.1 and 2.2). However, benefits from improved water quality accrue beyond regional jurisdictions. Overall, public research on natural resources and the environment accounted for 21 percent of total public agricultural funds in 2003, up from 17 percent in 1998 (fig. 3.2.2).

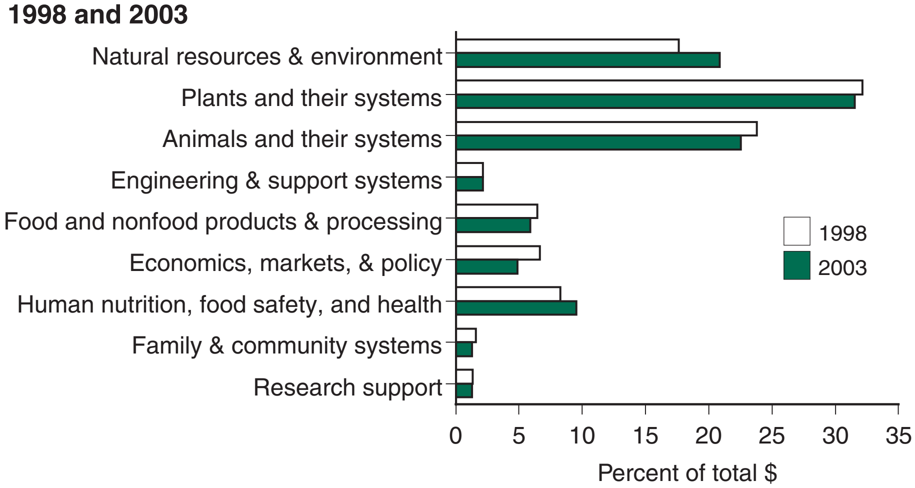
The research categories that we use may not capture all research that can benefit the environment. Scientists self-classify their research using USDA's Current Research Information System (CRIS) and may not consider "natural resource and environmental research" as the primary objective of their work. For example, plant breeders may produce resistant varieties that require fewer agricultural chemicals, which may improve water quality. Still, they may classify the research under "plants and their systems."

Private Sector Research and Development

Private industry has been playing a more important role in agricultural research, not only boosting research investments but also expanding into new areas of research. For more information, see the "Agricultural Research and Productivity" Briefing Room. Private industry expenditures on agricul-

Figure 3.2.2

Allocation of public funds for agricultural research, 1998 and 2003



Source: USDA Current Research Information System.

tural research have increased 50 percent in real terms between 1978 and 1998[1] (fig. 3.2.1). In 1998, 60 percent of private sector agricultural research expenditures were allocated to biological and chemical technologies, such as agricultural chemicals, plant breeding, and animal health, compared with only 19 percent in 1960 (fig. 3.2.3).

Advances in the biological sciences and expanded intellectual property rights (IPRs) protection for biological innovations have stimulated private sector efforts in technology development. Basic research in biology, microbiology, and computing created new technological opportunities for private agricultural research. For example, gene transfer technologies enable researchers to tailor crops for specific uses, such as crops resistant to disease, pests, herbicides, or harsh environmental conditions; and crops with increased nutrition or improved food processing traits. [See Chapter 3.3, "Biotechnology and Agriculture" for a more complete discussion of biotechnology-derived agricultural innovations.]

Expanded IPRs for biological inventions and new plant varieties have allowed innovating firms to capture a greater share of the benefits from research. The Patent Act of 1790 was established to "promote the progress of science and useful arts," but biological inventions were considered products of nature at that time, and were not thought to be patentable. The extension of IPRs to new plant varieties and biological inventions, including biotechnologies, has further stimulated private companies to invest in plant breeding. The Plant Patent Act of 1930 and the Plant Variety Protection Act (PVPA) of 1970 established plant breeders' rights for new plants and plant varieties. In 1980, a Supreme Court decision (Diamond v. Chakrabarty) established the use of Utility Patents for biological inventions, specifically microorganisms. Further decisions by the Patent and Trademark Office broadened the use of Utility Patents for plants (in *ex parte* Hibberd in 1985) and animals (in *ex parte* Allen in 1987). The number of plant patents, Plant Variety Protection Certificates (PVPCs), and utility patents issued over the last 30 years has risen (fig. 3.2.4). International organizations have

[1] Data were not available for private agricultural research funding beyond 1998 at the time of this writing.

Figure 3.2.3

Private agricultural research by industry, 1960 and 1998

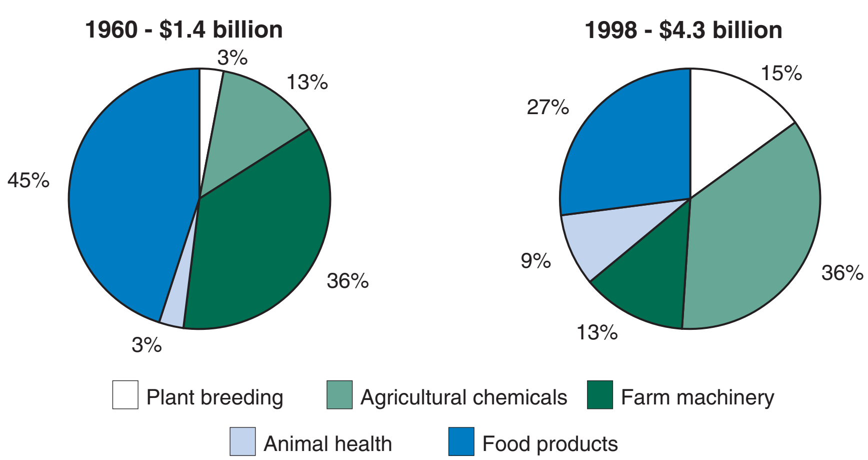
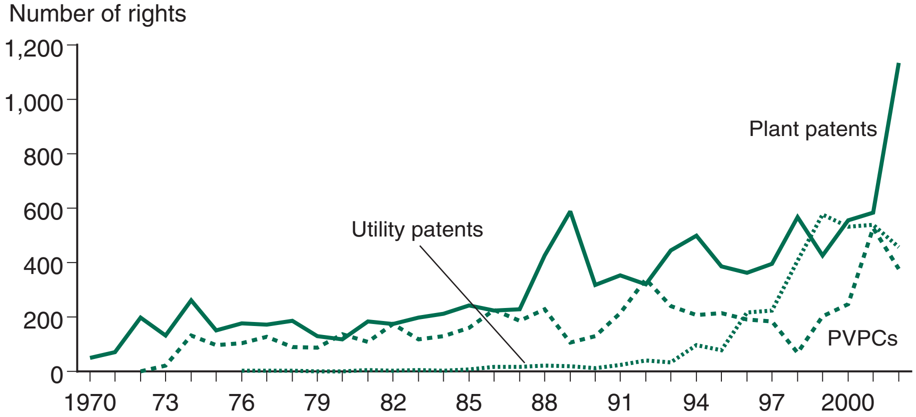


Figure in 1996 dollars.

Source: USDA, Economic Research Service.

Figure 3.2.4
Intellectual property rights issued for new plant varieties



Source: USDA, Economic Research Service.

attempted to harmonize intellectual property protection in order to facilitate trade and technology development.

Public and Private Collaboration in Agricultural Research and Technology Transfer

Another change affecting technology development in agriculture has been the growth in collaborations between the public and private sectors. Before 1980, U.S. patent policy limited collaboration between public and private researchers, since the Federal Government assumed ownership of any inventions that resulted from federally funded research. The Government Patent Policy of 1980 (Bayh-Dole Act) granted institutions "certainty of title" for inventions resulting from federally funded research, and allowed Federal laboratories to issue exclusive licenses for patents of their inventions. 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 public-private Cooperative Research and Development Agreements (CRADAs). This mechanism allows USDA to share technologies at various stages of development, research results, and scientific resources (though not money) with industry through joint research ventures.

Incentives for technology transfer may be very important, particularly for innovations that provide public-good benefits. Potential technologies developed in the public sector are not automatically marketed by the private sector. USDA and the SAES transfer a variety of innovations to private firms and directly to farmers, both shielded and unshielded (i.e., protected by IPRs or not) to ensure the provision of useful technologies to the agricultural sector (Day-Rubenstein and Fuglie, 2000).

Public entities like USDA can patent inventions meeting the criteria of the U.S. Patent and Trademark Office, then grant an exclusive/co-exclusive (most often), limited exclusive, or nonexclusive license to a private company to use or market the invention. In 2000, licensing revenue was less than 0.5 percent of USDA's R&D budget. Still, the licenses offer an incentive to private firms to develop and deploy the new technologies.

Other forms of cooperative effort between research entities include research consortia, which bring together several institutions to undertake joint research. These consortia increase funding support for strategic research and research that is considered to be long term and high risk (Fuglie and Schimmelpfennig, 2000). Large-scale efforts in plant genomics are underway to map, sequence, and analyze the genomes of several model plant species that are important for developing new crop varieties with desired traits.

Likely Research Trends

Several developments will influence the research portfolio over the next decade. Markets are beginning to develop for some public goods, such as products grown with "environmentally friendly" agricultural practices. If private firms can profit from providing products with desired social characteristics, research will accommodate such trends.

Another development that may affect future R&D investments is recent consolidation of seed, biotechnology, and agricultural chemical industries (Fernandez-Cornejo, 2004). There were 381 mergers, acquisitions, and other strategic alliances in the agricultural input industry between 1980 and 1998, and 10 firms accounted for almost half of that activity (King, 2001). Increased market power resulting from industry concentration and increased appropriability of technology may enhance incentives for private-sector innovation, leading to greater agricultural productivity. On the other hand, too much market power may inhibit technological advancement by creating barriers to entry for new firms and limiting access to critical technology and knowledge.

Developments in multiple scientific disciplines have led to several new fields: bioremediation, nanotechnology, genomics, proteomics, and bioinformatics. The expanded platform of knowledge will increase the options for agricultural research, development, and technology transfer.

References

Agricultural Marketing Service (various years). Plant Variety Protection Office.

Agricultural Research Institute (1985). *A Survey of Agricultural Research by Private Industry III*. Bethesda, MD.

Day-Rubenstein, Kelly, and Keith Fuglie (2000). "The CRADA Model for Public-Private Research and Technology Transfer in Agriculture," *Public-Private Collaboration in Agricultural Research: New Institutional Arrangements and Economic Implications.* Keith Fuglie and David Schimmelpfennig (eds.). Iowa State University Press, Ames, IA.

Fernandez-Cornejo, J. (2004) *The Seed Industry in U.S. Agriculture: An Exploration of Data and Information on Crop Seed Markets, Regulation, Industry Structure, and Research and Development.* AIB-786. U.S. Dept. Agr., Econ. Res. Serv. Feb.

Fuglie, Keith, Nicole Ballenger, Kelly Day, Cassandra Klotz, Michael Ollinger, John Reilly, Utpal Vasavada, and Jet Yee (1996). *Agricultural Research and Development: Public and Private Investments Under Alternative Markets and Institutions.* AER-735. U.S. Dept. Agr., Econ. Res. Serv. July.

Fuglie, Keith, and David Schimmelpfennig, editors. (2000). *Public-Private Collaboration in Agricultural Research: New Institutional Arrangements and Economic Implications.* Iowa State University Press, Ames, IA.

Huffman, Wallace, and Robert Evenson (2006). *Science for Agriculture: A Longterm Perspective Second Edition.* Iowa State University Press, Ames, IA.

King, John (2001). *Concentration and Technology in Agricultural Input Industries.* AIB-763. U.S. Dept. of Agr., Econ. Res. Serv. March.

Klotz, Cassandra, Keith Fuglie, and Carl Pray (1995). "Private-Sector Agricultural Research Expenditures in the United States, 1960-92." Staff Paper No. AGES9525. U.S. Dept. Agr., Econ. Res. Serv. Oct.

National Research Council (1996). *Colleges of Agriculture at the Land Grant Universities: Public Service and Public Policy.* National Academy Press, Washington, DC.

Patent and Trademark Office (2001). Data from online patent search.

Pray, Carl (1993). "Trends in Food and Agricultural R&D: Signs of Declining Competitiveness?" *U.S. Agricultural Research: Strategic Challenges and Options.* Robert D. Weaver (ed.), Agricultural Research Institute, Bethesda, MD, pp. 51-67.

Pray, Carl, and Keith Fuglie (2000) "The Private Sector and International Agricultural Technology Transfer," *Public-Private Collaboration in Agricultural Research: New Institutional Arrangements and Economic Implications.* Keith Fuglie and David Schimmelpfennig (eds.). Iowa State University Press, Ames, Iowa.

U.S. Department of Agriculture (various years, 1979-2001). Current Research Information System.