

## Research & Technology



# Biotechnology Research: Weighing the Options for a New Public-Private Balance

The revolution in biotechnology, coupled with strengthened patent protection for biological inventions, is toppling conventional wisdom about the research roles of the public and private sectors. Although the division of labor was never precise, a long-held belief is that the combination of a public sector specializing in relatively basic research and a private sector oriented toward applied research and technology development generates the highest return on the nation's total research and development (R&D) investments.

Today, however, it is increasingly evident that a sizable share of what was once considered exotic basic science, such as genomic mapping, is being conducted in the private sphere by large life science firms, such as Novartis, Monsanto, DuPont, and Celera, and by many smaller biotech companies. The expansion of their basic research programs explains in part why total research expenditures by the private food and agricultural industry have nearly tripled in real terms between 1960 and 1996, from about \$1.3 billion to \$4 billion, and why total U.S. investment in agricultural research is much larger now

than ever before. This shift in the role of the private-sector research poses new public policy questions and presents challenges for planning the public-sector agricultural research agenda.

Among the challenges facing R&D decisionmakers and analysts: Is there a unique and distinct role for public-sector research as the private sector's role expands? What is the appropriate relationship between public and private research entities? How do public researchers gain access to critical basic knowledge being generated by private firms? And should public research organizations be pursuing intellectual property protection as vigorously as private firms?

Answering such questions may require a new conceptual framework for public R&D decisions—a framework likely to evolve slowly in relation to the speed with which the biotechnology revolution is generating new knowledge of plant and animal genomics and stimulating development of genetically enhanced agricultural and agriculturally based products (*AO* March 1999).

### *Traditional View of Public-Private Split Is Fading*

The traditional economic rationale for a strong public role in research is based on the nature of R&D—i.e., the product is information which, unless kept secret, can be copied with minimal additional cost by anyone who wants to use it. Lacking the ability to sufficiently recoup (or “appropriate”) the returns on their research investments, firms would likely conduct too little research from the standpoint of potential benefits to society at large.

On the other hand, if firms are able to secure strong proprietary rights to research discoveries, the benefits of new knowledge are unlikely to be widely shared and many potentially beneficial uses may be precluded. A strong public-sector role in conducting as well as funding research helps ensure both a larger pool of R&D for the nation and broad dissemination of new discoveries to other scientists and innovators who can advance and apply them.

This logic has been used to support the idea that the public-sector role should emphasize basic research. Basic research has been the least appropriable category of research because pure knowledge, once discovered, is difficult to keep secret and its use by one person in no way precludes its use by another. Applied research, on the other hand, may result in a physical product or technology whose use can be restricted to those buying a copy.

Widely available basic research results are also likely to have the largest positive “spillovers”—that is, benefits that extend beyond the initial users and that often underpin further research discoveries. For example, knowledge of DNA structure has spawned and enhanced biomedical research discoveries all over the world. By concentrating on basic research, the public sector can maximize spillovers to the benefit of further advancements in both public- and private-sector research, as long as the results of public-sector basic research remain nonappropriable public goods.

Agriculture and agricultural technology have characteristics that have further shaped the public sector's role in U.S.

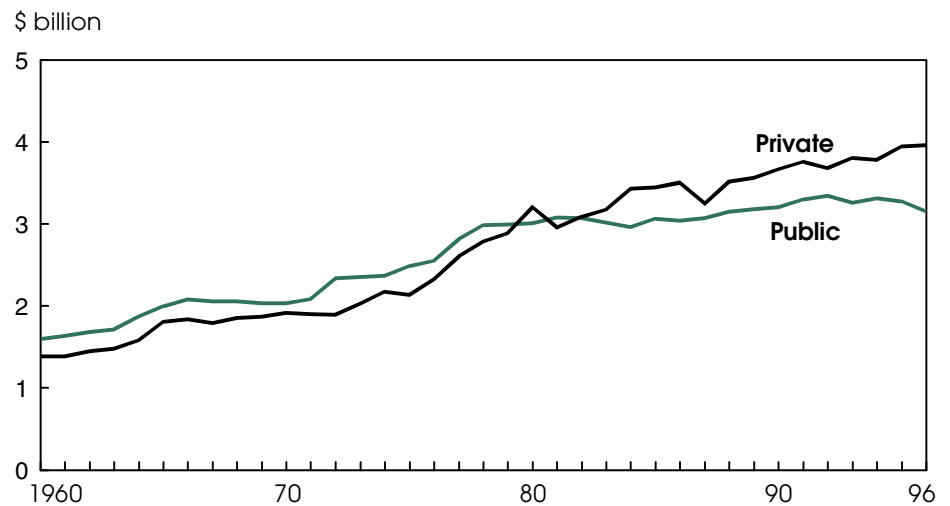
agricultural research over the last 100-plus years. Some research areas related to public concerns about agricultural production and the food system—for example, enhancing environmental quality, conserving genetic resources, improving the nutritional status of consumers, mitigating food safety risks, and protecting biological security of the food system—may have both basic and applied components that are critical for building the science base for public policy. However, such areas of research are unlikely to attract adequate private investment because prospects for financial returns are relatively low or difficult to assess.

Further, economic returns from investing in development of many agricultural production technologies, particularly self-pollinated seeds and new livestock breeds, have historically been difficult for private inventors to appropriate, not only because the products themselves provide the means to reproduce them, but also because biological inventions until recently were not subject to standard patent law. With no patent restriction, a farmer could, for example, use the seed of self-pollinated plants in the next planting season, or even sell the next generation of seed to others. Consequently, investment in crop and livestock breeding research has been historically a largely public-sector effort.

The extent to which private firms and individuals can profit from what were previously considered basic scientific discoveries changed dramatically following a 1980 Supreme Court decision that made it possible to obtain the strongest form of intellectual property protection (utility patents) for living organisms. In the last 10 years especially, the rate of patent application and patent granting for biological inventions has accelerated rapidly, particularly for genetically engineered plants and animals as well as for individual genes with specific uses (“utilities”).

In a departure from past experience with biological innovation, a number of utility patents are for biological materials that *enable* scientific research. Examples of *enabling technologies* are “promoter genes” (genes that control or modify the action of other genes), “marker genes” (genes that, when discovered in an organism, facilitate identification of an associ-

### Private Agricultural Research Expenditures Have Overtaken Public



1996 dollars.

Economic Research Service, USDA

ated trait that is otherwise not detectable), and specific cellular-level enzyme activation processes. The value of these enabling technologies is a function of their importance in the production of a biotechnology end product.

Development of a genetically engineered, salt-tolerant crop cultivar (a patentable final product), for example, may rely on use of a bacterium-based gene transfer technique (an enabling technology), which is itself patentable and which may require a license for legal use. Biological enabling technologies have been likened to computer software in that both have fairly recently been deemed patentable, both can provide intermediate means to a final goal, and both could easily be “pirated” to produce final goods were it not for intellectual property protection.

The strengthening of intellectual property law for biological materials is essential fuel for the engine of private-sector biotechnology innovation. It allows those who invest scientific resources in research to recoup their (often substantial) development costs through licensing rights to use an enabling technology or retaining exclusive sales rights (for 20 years maximum) on a final biological product. Basic science can now lead to unique and patentable properties of specific biological materials. At the same time, advances in biotechnology—e.g., fast and accurate

“DNA fingerprinting” to identify patented DNA sequences—have strengthened companies’ ability to protect their intellectual property. There is, therefore, a private incentive to pursue what historically has been considered public-sector basic science, because the results are no longer pure public goods.

Continued consolidation, vertical integration, and concentration in the agricultural seed and chemical industries have raised some concerns about expansion and control of agricultural R&D by private interests. With very large life-science-based firms conducting appropriable research on agricultural biotechnologies, questions arise about the concentration of power proffered by patents and other means of protecting intellectual property. However, evidence to date indicates that licensing of many enabling technologies whose patents are owned by private firms is widespread. So, even if few firms manage a large body of intellectual property, licensing may temper the manifestation of substantial market power.

Of potentially greater concern is vertical integration of agricultural biotechnology firms along a portion of the food supply chain. For example, a chemical firm that owns a seed company focused on major row crops may have an incentive to restrict the use of an enabling technology to its own seed firm in order to limit

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### Government Broadens Protection for Biological Discoveries

While limited types of patent protection for plants have been available since 1930, recent government actions have significantly expanded the scope of safeguards for new biological discoveries. The landmark *Diamond v. Chakrabarty* decision by the Supreme Court in 1980 ruled that a genetically engineered organism could be patented under existing law. Subsequently, the U.S. Patent Office set precedent rules during the 1980's that permitted granting utility patents to new types of plants and plant parts (including seeds, tissue cultures, and plant genes), and also to animal genes and new and unique breeds of nonhuman animals.

During that decade, a series of new laws also changed the nature of intellectual property protection available to public-sector discoveries. In 1980, the *Bayh-Dole Patent Policy Act* allowed individuals and institutions to receive patents and then grant licenses for the results of research conducted with Federal funds. The *Stevensen-Wylder Technology Innovation Act* of 1980, later amended by the *Federal Technology Transfer Act* of 1986, authorized cooperative research and development agreements (CRADA's) as a mechanism for public-private research collaboration, and directed the public sector to transfer rights to explore commercial possibilities to the private sector for development and economic rent (profit) appropriation.

Plant breeding activities by traditional seed companies have clearly responded to the new forms of intellectual property protection by intensifying their research efforts. In recent years, the private-sector plant breeding effort—measured in scientist years—was more than twice the public-sector effort in USDA and state agricultural experiment stations combined. Although seed companies continue to emphasize cultivar development, a study of plant breeding R&D in the U.S. indicates that 40 percent of scientists specializing in genetic enhancement and basic research are employed in the private sector, with much higher shares for scientists studying hybrid crops. Nearly half of all breeders of pureline cereal crops—those that produce true-to-type seed from generation to generation—are in the private sector. Not surprisingly, the private sector owns the majority of Plant Variety Protection Certificates and patents awarded for multicellular living organisms.

competition in new row-crop seed. This in turn would limit the number and type of end products likely to be developed from that enabling technology to a level probably lower than if its use were licensed to many seed companies (including firms that produce specialty crop seed along with some major row-crop seed).

#### Sorting Out a Public Research Role

The strengthening of intellectual property protection for biological inventions has weakened one of the historical justifications for public support of agricultural research—i.e., the inability of private entities to sufficiently profit from research. By the same token, another major justification—i.e., to maximize knowledge spillovers by facilitating broad dissemination of research finding—appears to have been reinforced. These developments suggest the need for decisionmakers to reevaluate public research policy and to identify strategies that generate the great-

est social return on R&D investments. Key to policy planning is determining when and how the public sector should interact with the private sector—i.e., whether an area of inquiry is purely in the public domain, is appropriate for public-private partnership, or is most suitable for the public sector to pursue to prevent control by the private sector.

Given that some motivations for research are distinctly public—e.g., mitigating food safety risks, improving nutritional health, and enhancing environmental quality—they are unlikely in and of themselves to be a focus for private endeavors. One benefit of stronger intellectual property protection for agricultural research is that by creating an incentive for private basic research, it offers an opportunity to redistribute limited public resources to critical areas in the public domain. For example, genetic resource conservation—storing and conserving genetic resources for the future—may be viewed as a kind of insurance against loss of rare biological

material because it gives society the option of drawing upon these banked resources at a later time.

Which genetic resources will be needed for breeding in the future, and when, is unknown. Uncertainty of a return to such investment over a long time span means that genetic resource conservation would be seriously underfunded by the private sector in relation to its longrun value to society. This vital responsibility—currently overseen by the National Plant Germplasm System (NPGS)—is generally agreed to fall within the public domain.

Carving out areas of distinctly public-sector research is, however, likely to be more difficult than in the past, because it is increasingly likely that some knowledge and/or biotechnological tools needed for public-sector research thrusts will result from private activity and will be patented. For example, a project to genetically modify papaya for disease resistance—aimed primarily at aiding less-developed countries not likely to compete with U.S. commercial interests—was complicated by the need for university-based researchers to negotiate a half-dozen licensing agreements with private firms.

The potential for public-sector research to benefit from private-sector discoveries suggests a need to expand opportunities for partnerships. Despite many complementary research interests, public-private partnerships are not easy to forge, and disagreements over patent arrangements and licensing rights can be major barriers.

Drawing firms into such agreements—especially where making the findings readily available may be one of the major goals—can be very difficult. Nonexclusive or limited-exclusive arrangements that assure broad dissemination of findings may better serve the public interest, but first right to exclusively license an invention may be the powerful inducement necessary for firms to agree to participate. Alternatively, private firms may become willing to give up some intellectual property protections if they receive something beneficial in return—such as access to scientific personnel, techniques, infrastructure, or even professional credibility from association with a public endeavor—in effect, some in-kind compensation that



enhances their research efforts but would be more costly to procure through other means. For example, in striving to forge partnerships with multinational firms, the network of international agricultural research centers (known as the CGIAR system) has stressed that it offers access to germplasm collections and the mantle of CGIAR's credibility and goodwill in countries around the world.

One existing vehicle for public-private partnership is the cooperative research and development agreement (CRADA), a mechanism used by USDA's Agricultural Research Service (ARS) since enactment of CRADA legislation in 1986. USDA has typically used CRADA's to speed the transfer of technology developed in the public sector to the private sector for development of commercial applications. However, ARS has seen very few patents arise from the 900 CRADA's established to date, which means there have been few exclusive patent licenses associated with these cooperators. In the current environment, the focus of CRADA's and other collaborations may shift toward cooperative research projects or programs with multiple, complementary outcomes for public and private participants.

A provocative question today is whether the public sector should strategically target and perhaps defensively patent research in order to guarantee access to and broad dissemination of certain critical types of new knowledge that might otherwise be "locked up" by private firms. An example of biological research critical to the public interest is the study of *apomixis*, asexual reproduction through seed. The *apomixis* trait enables some flowering-plant species to produce seedlings that are genetically identical to the mother plant, in effect allowing hybrid cultivars to clone themselves. New knowledge gained from *apomixis* research could generate a worldwide revolution in the economic development and use of hybrid cultivars, including major food crops, but potential limitations on biodiversity are profound. Identifying such research areas for the public sector to undertake requires a broad vision of scientific frontiers and their possibilities, coupled with insights into the investment strategies of private firms.

## How Is *Agrobacterium tumefaciens* Like Computer Software?

*Agrobacterium tumefaciens* is a pathogenic microorganism that naturally inserts its own genes into plants that it infects. This trait has been refined for biotechnological development, where *Agrobacterium* is used to transfer genes from other organisms into plants. Although other gene transfer methods are available, this enabling technology remains one of the easiest and most effective methods for creating genetically modified organisms (GMO's).

Few would disagree that intellectual property protection (patents) should be available to inventors of computer software—tools designed to enable operation of computers. But the idea of intellectual property protection for biological tools is somewhat harder to envision. Yet biological tools such as *Agrobacterium*, like computer software, are:

- intermediate products whose value can only be realized through their use in accomplishing another task in a different final product (a genetically engineered organism or a computer);
- easily accessible, whether or not one has a license to use them, so that the potential for "pirating" reinforces the need for protection of the intellectual property they embody;
- able to resist exact replication, but can be imitated by similar products; and
- undergoing scrutiny by the legal system because of fears that producers of final products for which these intermediate products are essential may exercise undue power in the marketplace for the GMO's/computers they enable.

New knowledge of biotechnology promises dramatic change in the ability to create agricultural production and food industry applications to benefit humanity and the natural environment. Some of this knowledge may result from private research organizations—which seek to restrict distribution to shield potential returns—and some may be uncovered within the public domain. In either case, obtaining that knowledge requires expensive, long-term investments.

Determining how public agricultural research institutions—principally ARS and state agricultural experiment stations—fulfill their longstanding roles as producers of knowledge for the public good requires more complex and strategic decisionmaking than just a decade ago. New criteria are necessary for assessing *what* the public sector funds, *where* the public sector should invest, and *how* circumstances of industry structure affect expected returns to public investment.

One way to judge the value of a public-sector role in any particular type of agricultural research is to ask: Who is likely to benefit from the fruits of this research? For example, ARS reviews the plan of work for a potential CRADA to determine

whether the outcome of the research could lead to applications in specific areas of end use, or to more basic discoveries of a new approach or enabling technology. The agency frequently declines collaborations that could lead to monopoly power over technologies with public-good value.

Other critical questions include: How are the benefits of the research likely to be distributed along the food supply chain among input suppliers, farmers, processors, and consumers? Are public benefits likely to exceed public costs? The answers will help determine whether one form of public-private interaction is superior to another, and to indicate how public-sector research institutions and other public policy participants might influence the private sector—the new, major actor in agricultural R&D—to pursue actions that maximize the public good from the biotechnology revolution. **AO**

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A list of suggested readings is available from the authors.