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The Complementary Roles of the Public and Private Sectors in U.S. Agricultural Research and Development

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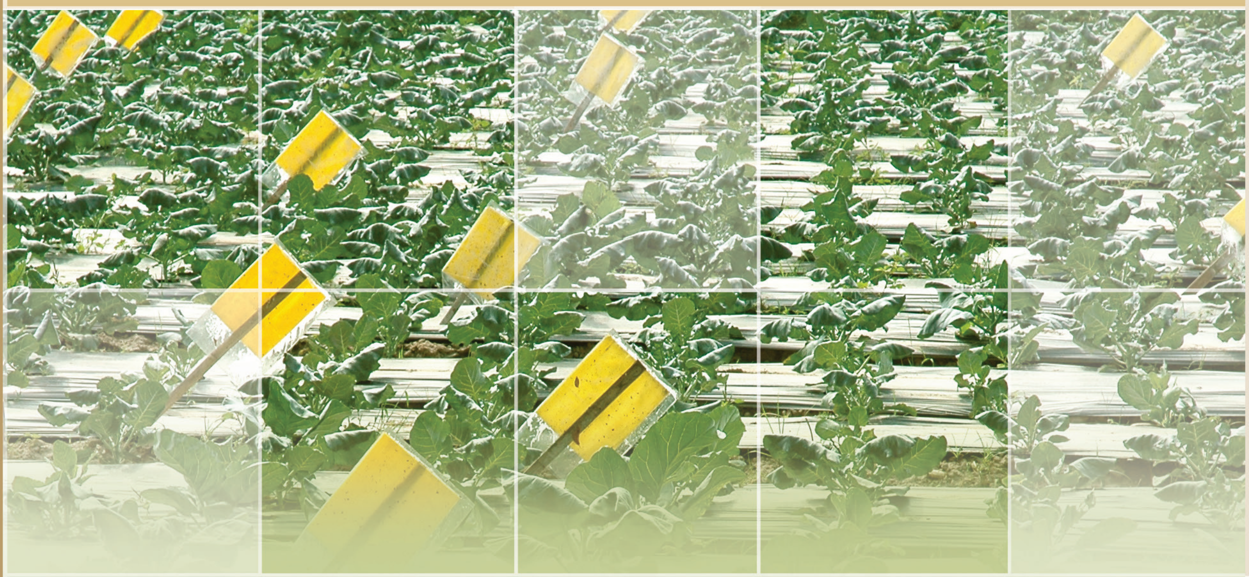


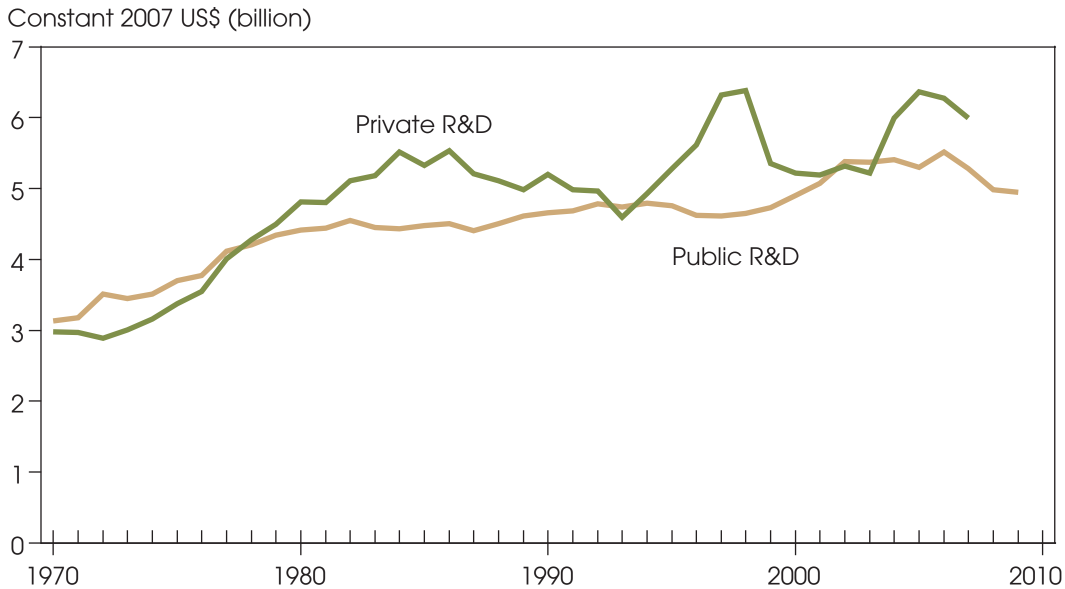
This brief examines the funding and performance of agricultural research and development (R&D) to assess the evolving roles of the public and private sectors in the U.S. agricultural research system. There is a clear long-term trend toward greater private-sector funding and performance of R&D. In 2007, the private sector performed 53 percent of total food and agricultural research in the United States, and privately funded R&D has grown faster than publicly funded R&D over the long term (fig. 1).

- The increase in agricultural R&D conducted by the private sector reflects the increasing prevalence of public-private partnerships and other policies to enhance private returns on R&D, and the private companies' incentive to capitalize on new opportunities for innovation from prior public investments in the agricultural sciences.
- Most of the growing share of private-sector agricultural R&D supports researchers working in private companies who focus on topics and issues with the highest expected private returns. Relative to the public sector, this leads to a smaller portfolio of research topics and a greater emphasis on short-term research.
- Public-sector funders and performers of R&D play a largely complementary role by emphasizing social returns in the selection of research topics and valuing rapid and widespread disclosure of new knowledge.

Correction: On January 7, 2013, Figure 3 was corrected to reflect a units error in the original figure. The corrected figure shows agricultural R&D expenditures ranging from $0 to $3.5 billion depending on category of spending (previously, the figure misreported these expenditures by a factor of 10, or from $0 to $35 billion).

Figure 1

Long-term growth in funding for U.S. food and agriculture research and development (R&D) is higher in the private sector



Source: Fuglie et al., 2011.

Public and private funds support research at different institutions

The U.S. agricultural research system receives funding from three primary sources: (1) Federal appropriations, (2) State appropriations, and (3) nongovernment sources (chiefly private-sector firms but also charitable foundations). These funds support research that is carried out by three main types of institutions: (1) Federal research facilities; (2) State-affiliated land-grant universities, State agricultural experiment stations (SAES), and other cooperating institutions such as schools of forestry, veterinary schools, and 1890 and 1994 land-grant institutions; and (3) private laboratories and experimental sites, nearly all of which are owned and operated by for-profit firms (fig. 2). Private institutions include firms in the food manufacturing, chemical, equipment, pharmaceutical, seed, and biotechnology industries that provide inputs to the farm sector and process agricultural commodities.

Federal research facilities receive funding almost exclusively through Federal appropriations, with a small contribution (less than 1 percent) from firms through Cooperative Research and Development Agreements and other arrangements. Firms performing agricultural R&D fund nearly all of it themselves, receiving very little funding from public sources except for Small Business Innovation Research grants and research contracts. By contrast, universities, SAES, and other State institutions draw on Federal, State, and private funds to support their R&D. According to what State institutions report to USDA (2007), Federal funds from USDA and other Federal agencies typically support 50 to 60 percent of the agricultural R&D at State institutions, and State-level appropriations support roughly another third.. Non-government sources of funds—including research contracts from private firms, technology licensing fees, and foundation grants—provide the remaining 20 percent of research funding for these State institutions.

Public and private R&D differ in goals, specialization

Private firms invest in R&D to earn the highest possible expected *private returns*, the economic benefits from new products and technologies that firms can appropriate as profit. But private returns do not fully reflect the benefits from R&D to customers, consumers, or competitors. *Social returns* to R&D investment include both the firm's private returns as well as economic benefits to these other groups in society.

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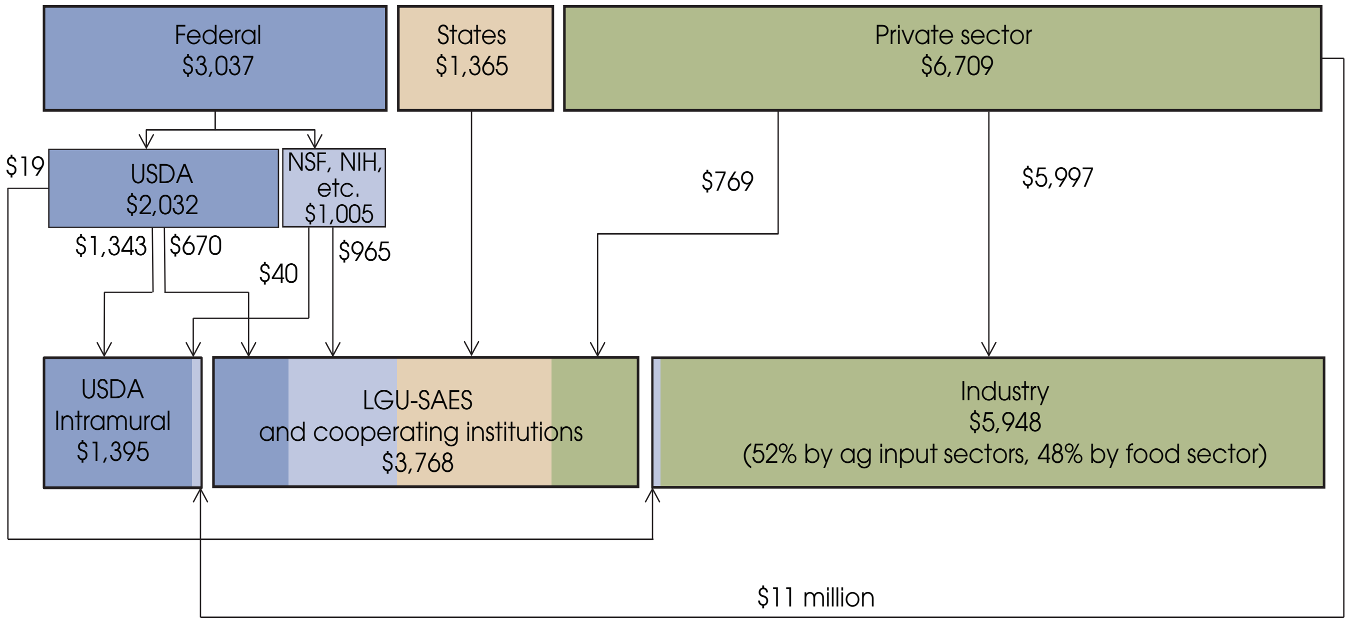
Figure 2

Federal, State, and private institutions both funded and performed food and agricultural research in 2007

The U.S. Food and Agricultural Research System

Funders and performers of U.S. food and agricultural research in 2007 ($ million)



Total U.S. food & agricultural R&D performed: $11,110 million ($5,163 million public + $5,948 million private)

Source: Public research and development (R&D) is from U.S. Department of Agriculture (2007) except for USDA grants to industry, which is from the NSF (2009). Private R&D is from Fuglie et al. (2011). Numbers may not sum due to rounding. NSF = National Science Foundation; NIH = National Institutes of Health; LGU = land-grant universities; SAES = State agricultural experiment stations.

The argument that private returns to R&D do not fully reflect the benefits of technological progress to society suggests the private sector underinvests in R&D from a societal perspective and supports the use of public policies to encourage additional private research. Some policies provide incentives that increase private returns to R&D such as patent protection, other intellectual property rights, technical assistance, and R&D tax credits. Public funding and performance of R&D can also address private underinvestment by expanding the knowledge base to create new opportunities for innovation.

Social returns to R&D include an important element not reflected in private returns: the cumulative contributions of discoveries and inventions to subsequent R&D performed by other researchers in society. The potential for cumulative contributions depends on the disclosure and diffusion of new knowledge through various channels such as scientific publications. Professional norms at publicly supported research institutions encourage open, rapid publication of science, which enables other researchers to replicate, validate, and contribute to new knowledge. Universities also combine their research mission with the education and training of future scientists, which further enhances society's capacity for cumulative contributions. A study of 200 top R&D performing firms found that university research is an important source of knowledge for industrial scientific publications (Adams and Clemmons, 2008). Scientists affiliated with 110 top universities communicated research findings in nearly 200,000 articles in agriculture journals from 1981 to 1999, compared with fewer than 6,000 by scientists affiliated with 200 top R&D firms. While the market-oriented nature of private firm research may limit publication opportunities in scientific journals, private firms also have incentives to limit the availability of new technology and knowledge through trade secrets, patent protection, and other efforts to appropriate a greater share of R&D benefits. Such intellectual property protection encourages investment but can hamper social benefits to R&D from scientific exchange.

Public and private R&D have different complementary roles

Beyond differences in how new knowledge is disclosed, public and private funders tend to invest in different "portfolios" of agricultural research topics. Private firms specialize in fewer topic areas and focus their R&D in areas with established product markets, such as food, agricultural inputs like crop seed and chemicals, farm machinery, and veterinary pharmaceuticals (fig. 3). Public institutions invest in a broader portfolio of topics than private firms. For instance, public R&D investment addresses areas such as the environment and natural resources, human nutrition and food safety, and social and community development. Research in these areas provides social benefits that are widely diffused and difficult to capture through private innovation.

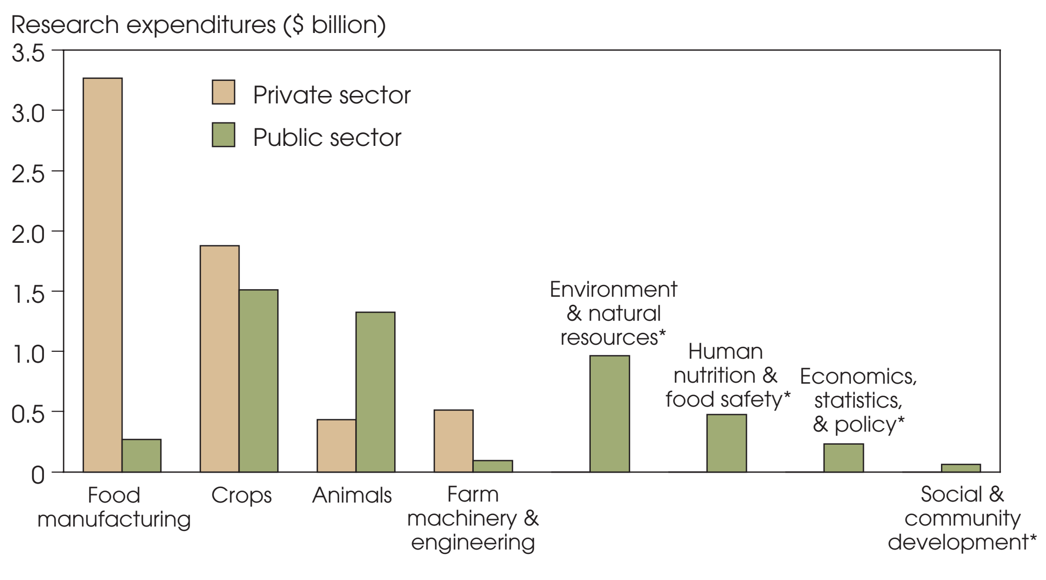
Crop research and development is one area that receives a significant amount of both public and private investment, so public and private sector roles are more difficult to delineate. Public investment may crowd out private investment by supporting research that otherwise would have been done by private organizations. Or public investment may complement private R&D by expanding the knowledge base needed to create possibilities for innovation.

The evidence favors a complementary relationship. For example, a 2001 survey of U.S. seed companies found that three-fourths of private crop breeding investment was directed at just three commodities—corn, soybeans, and cotton (Traxler et al., 2005, personal communication). These are the largest U.S. crop seed markets, where large private returns encourage the most private R&D. Public R&D is spread more evenly across the full set of crops, including crops such as wheat where social returns to research justify public investment but high development costs and low appropriability reduce private returns. Public R&D is also more geographically dispersed, with experiment stations in each State. Because agriculture is heavily influenced by factors that vary across regions such as climate, natural resource quality, and transportation costs, the geographic dispersion of public R&D addresses challenges in a broader set of agricultural production systems.

Public R&D focuses more heavily on basic or "pre-technology" research that is difficult to patent and commercialize, while most private R&D emphasizes applied research and product development. For

Figure 3

Public research addressed a broader set of research topics than private research in 2006



*Private-sector investment is likely to be greater than zero, but reliable figures could not be obtained.

Source: Public R&D is from the U.S. Department of Agriculture (2007) based on Knowledge Area classifications. Private R&D figures are from Fuglie et al. (2011).

example, decades of publicly funded research in molecular genetics and biotechnology in the latter half of the 20th century enabled private firms to develop new techniques with commercial potential in agriculture. Complemented by new policies that strengthened intellectual property rights over crop varieties and genetic traits, these scientific and technological advances led to a surge in private-sector investment in crop breeding and biotechnology R&D (Fuglie et al., 1996). Between 1980 and 2010, R&D spending by U.S. seed and crop biotechnology companies rose from $100 million per year to more than $2 billion annually in constant 2010 dollars (Fuglie et al., 2011).

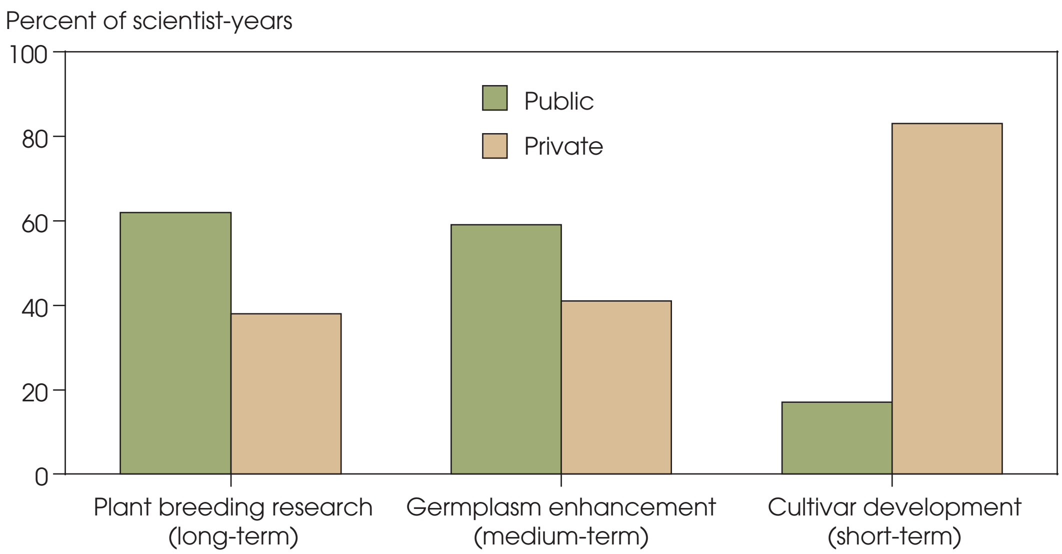
A comprehensive survey of public and private plant breeding in 1996 found that most private crop breeding R&D focused on downstream development of cultivars (cultivated crop varieties) while public R&D tended toward long- and medium-term research projects on plant breeding methods, identification of new traits, and germplasm enhancement to improve parent breeding materials (fig. 4). As the private sector increased investment in applied breeding, public research shifted to more basic R&D activities (Fuglie and Walker, 2001). Other studies of plant breeding (Pardey et al., 1996; Lesser and Kolady, 2011) emphasize the contributions of genetic material from publicly maintained elite germplasm used to develop private cultivars.

Other studies that have looked at public and private R&D throughout the U.S. agricultural research system also found their relationship to be complementary rather than duplicative. Both Wang et al. (2009) and Tokgoz (2006) found that private investments in agricultural R&D were significantly correlated with past trends in public spending on agricultural and life sciences research. The authors of these studies attributed this correlation to (1) scientific advances from public R&D that created new technological opportunities for private firms to commercialize, and (2) the higher education and training function of university research that expanded the pool of scientific human capital for private firms to hire. A third study, using citations data from scientific publications, found that total citations from private research to university publications increased, and that firms citing more university research had a higher likelihood of producing patentable technologies (Toole and King, 2011).

The agricultural chemicals industry also demonstrates the complementarity of private and public R&D. Companies that develop new agricultural chemical products devote most of their R&D toward regulatory

Figure 4

In crop breeding, the public sector emphasized longer term research and the private sector dominated development of cultivated varieties in 1996



Source: Frey (2000). Estimates are based on a survey of 90 Federal and State research institutions and 329 private seed companies. For each research area, the shares sum to 100 percent of the scientists reported in the survey to be working in that area.

testing, product registration, and product marketing, and many producers of existing "generic" products do minimal R&D. Public R&D in crop protection often addresses basic research questions about the biology of crops and crop pests and applied research on the use of chemicals in production systems, development of resistance, and integrated pest management practices (Fuglie et al., 2011).

Animal agriculture has not seen a similar surge in private R&D investment, but public and private roles are nonetheless complementary. The public sector performs a majority of animal breeding and genetics R&D, while most of the private spending on animal agriculture shown in Figure 3 targets pharmaceutical animal health products (Fuglie et al., 2011). Private R&D in breeding and genetics is lower in animal agriculture relative to crops in part because of incentives that vary markedly among animal commodities (higher for poultry, lower for large ruminants) and consumer acceptance and regulatory frameworks for genetically modified animals that remain unsettled.

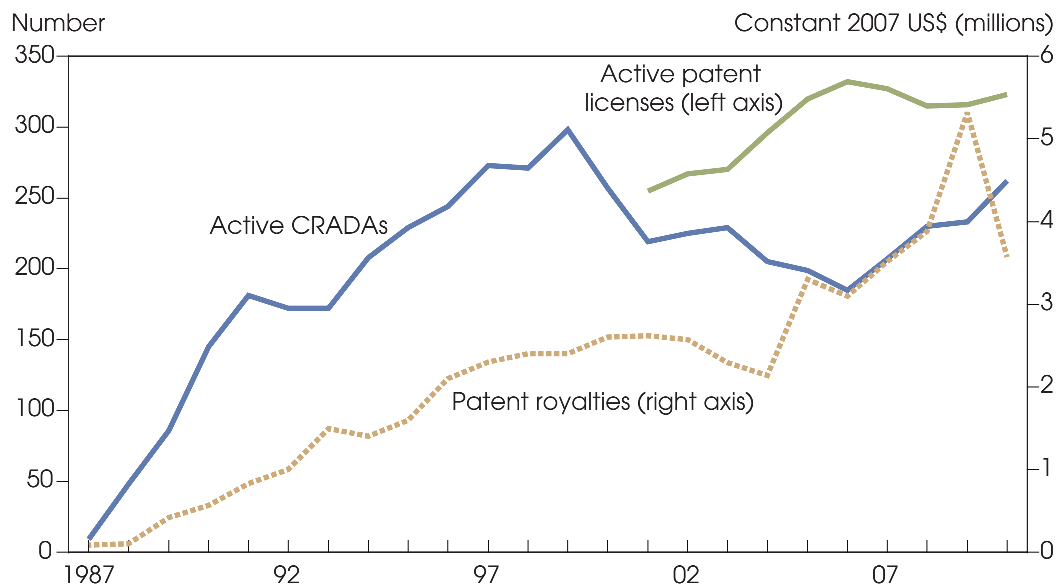
Policies and partnerships combine strengths to enhance the agricultural research system

With a shift of overall food and agricultural R&D toward the private sector, public research institutions have developed new strategies for partnering with private firms. New laws and policies provide vehicles for formal collaboration between public and private research institutions. Technology transfer policies encourage interaction of public and private R&D at different phases of technological development. When researchers at publicly funded institutions produce discoveries with commercial potential, they can obtain patents on these discoveries and license them to companies interested in further commercial development. This allows public researchers to focus on their public research missions and hand off commercialization to private technology partners. Exclusive licenses of patented technology reduce appropriation risks and raise private returns for commercial partners, thereby increasing incentives for firms to invest in downstream development, marketing, and production.

When the nature of R&D requires closer interaction, Cooperative Research and Development Agreements (CRADAs) provide a contractual mechanism for public and private researchers to collaborate. The use of both patent licensing and CRADAs by the USDA has grown since these arrangements were first enabled

Figure 5

USDA uses public-private R&D partnerships to facilitate technology transfer



Source: Data from 2001 are from Annual Reporting on Technology Transfer in USDA, Office of Technology Transfer, Agricultural Research Service. Earlier data are from Heisey et al. (2006).

through legislation in the 1980s (fig. 5).Through these agreements, government-owned and operated labs can partner with private firms to share data, facilities, and research results (Guston, 1998; Day-Rubenstein and Fuglie, 2000). Firms engaged in a CRADA are able to protect proprietary information and negotiate exclusive licenses for CRADA inventions. While the use of CRADAs, patenting, and other technology transfer instruments could potentially divert public research away from its central mission (National Research Council, 1995), such arrangements may also draw private capital into areas that serve important societal needs but where market failures are most evident, like human nutrition and natural resource conservation (Day-Rubenstein and Fuglie, 2000).

Another mode of public-private cooperation is when private interest groups, such as farmer commodity organizations, levy a small assessment on their sales to support research at public institutions. Federal legislation has permitted agricultural producer groups to make such "checkoffs" mandatory for research and promotion, but support for research through this mechanism in the United States has been minimal (Alston and Pardey, 1996). Some countries, notably Australia, have experimented with a model in which the government matches producer levies for public research. Recently, Australia has also instituted a system of end-point royalties based on sales of improved varieties as a way of enforcing intellectual property rights and encouraging more private investment in crop development. In the Australian experience, these institutional innovations appear to have strengthened private support for agricultural research and improved its efficiency and coordination (Alston, Gray, and Bolek, 2012).

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