Public Support for Agricultural Research

There are significant new challenges and opportunities for the Federal-State agricultural research system. Public expectations have changed about the future directions for agricultural technology, and a strong private sector capacity in agricultural research has emerged. These trends raise questions concerning the appropriate level of public support for agricultural research and the organization and allocation of resources among competing research goals.

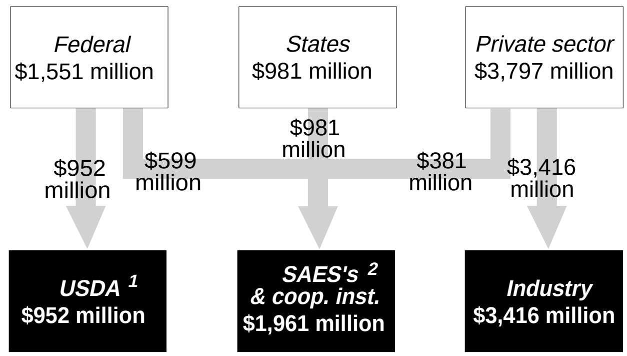
The Federal-State Partnership in Public Agricultural Research

The public system of agricultural research in the United States is based on a Federal-State partnership created in the latter-half of the 19th century. The Federal Government supports intramural research at USDA research agencies (Agricultural Research Service, Forest Service, and Economic Research Service). It also funds extramural research at State institutions (administered by the Cooperative State Research, Education, and Extension Service, or CSREES).[2] The State component is built upon a joint teaching-research-extension mission carried out by the land-grant universities and the SAES's.[3] A combination of Federal, State, and private monies supports the State system.

In 1992, nearly two-thirds of the $1.55 billion spent by the Federal Government for agricultural research went for inhouse research at USDA agencies (fig. 3). The remaining third was distributed to State institutions. State governments allocated $981 million for agricultural research, all going to the State system. The private sector spent more than $3.7 billion on food and agricultural research. Of these funds, $3.4 billion was for research in their own laboratories, and $371 million went to State institutions. Private-sector contributions to the State system include $143 million in direct grants from industry, $116 million for product purchases and patent license fees, and $121 million from other sources (such as grants from nonprofit foundations). In total, the State system received $1.96 billion for agricultural research in 1992. Federal funding for the State system is designed to draw each State into the agricultural research partnership. The Hatch Act accomplishes this by making Federal grants for agricultural research available to a State only if it matches the Federal contribution with its own funds. This effort has clearly been successful; State funding of the SAES system now significantly outweighs the Federal contribution.

The argument for Federal (in addition to State) funding of the State system rests on the concept of interstate "spillovers." Some portion of the economic benefit from research conducted in a State accrues to the State's own producers and consumers, and some portion "spills over" to consumers and producers in other States. If a State considers only the benefits of its research to its own producers and consumers, it will tend to invest less than what would be optimal from a national perspective. The argument is similar to the case of a private firm underinvesting in research because it cannot capture

Figure 3
Sources and flows of funding for agricultural research in 1992



[1] Includes research by Agricultural Research Service, Forest Service, Economic Research Service, and National Agricultural Library.
[2] SAES's are State agricultural experiment stations; coop. inst. include the 1890 schools, forestry schools, and veterinary schools.
Sources: Economic Research Service. Data for Federal and State research expenditures derived from USDA, *Inventory of Current Research*; data for private sector/industry research expenditures estimated from Klotz, Fuglie, and Pray (1995).

[2]The Cooperative State Research Service and the Cooperative State Extension Service were combined to form CSREES in the 1994 reorganization of the USDA.

[3]Besides the land-grant universities and the SAES's created by the 1862 Morrill Act and the 1887 Hatch Act, other components to this system have been added over time. The "Second Morrill Act" of 1890 established a system of colleges free from racial discrimination, leading to the "1890 Schools." The 1977 Evans-Allen Act provided funds to support agricultural research at these institutions. Federal funds for forestry research were substantially increased in 1962 with the passage of the McIntire-Stennis Act. Section 1433 of the Food and Agriculture Act of 1977 made research funds available for veterinary schools. These Acts, along with the Hatch Act, made block grants available to State research institutions based on a formula that determines the share of Federal dollars going to each State. In this report, the "State system" or "State institutions" refer to State agricultural experiment stations and other cooperating institutions, (such as 1890 schools, forestry schools, veterinary schools, and other academic and private institutions) supported by USDA formula funds.

all the returns. Furthermore, States will tend to favor applied and technology development research at the expense of more basic, or pre-technology research, since the former is likely to have less interstate spillover (see box, "Basic Research, Applied Research, and Technology Development"). Advances in pre-technology research, on the other hand, are likely to spill over to other States' producers. This is because these findings are likely to contribute to the development of production technologies suitable to a range of climatic conditions or even multiple commodities. Empirical analyses support the hypothesis that interstate spillovers from agricultural research are significant (Evenson, 1989).

Besides investing in the States' public research programs, the Federal Government maintains its own inhouse, or intramural, agricultural science expertise (see box, "Federal Support for Intramural versus Extramural Research"). There are at least two key reasons for maintaining a strong intramural research base. One reason is that the effectiveness of the State system depends on regional and interregional coordination and linkages provided through national program leadership in the USDA. For example, Ruttan (1982) argues, "The overlap of Federal support and coordinating services made it possible to give more concentrated attention to specific problems of crop improvement of common importance to several States than would have been possible if researchers in each State had worked in isolation. This involvement with the State experiment stations gave the USDA's research program greater access to basic science capacity in fields such as genetics, entomology, and physiology than could have been assembled with the Federal research system" (p. 78).

The second major reason for intramural research is that there are research problems and issues of national importance that may receive too little attention from

Basic Research, Applied Research, and Technology Development

Research and development (R&D) cover a broad range of investigative activities. The National Science Foundation (NSF) defines "basic research" as research conducted to gain a more complete understanding of the subject under study, without specific applications in mind. The NSF defines "applied research" as research aimed at gaining knowledge to meet a specific, recognized need. "Technology development research" is defined as the systematic use of research knowledge in the production of useful materials, devices, systems, or methods (National Science Foundation, 1993, p. 94). One problem with the NSF definition is that the characterization of a research activity depends on the scientist's interpretation and motivation for the research. What may be basic research to one scientist may be applied research to another.

Huffman and Evenson (1993) developed a structural representation of the R&D system for agriculture. They defined R&D activities as belonging to (1) the general sciences, (2) the pre-technology sciences, or (3) technology invention. Innovations from these activities result in products that can be extended to final users, for example farmers, consumers, and government agencies. Some of the fields of science and technology that characterize these activities are:

General sciences	**Pre-technology sciences**	**Technology invention**
Chemistry	Soil physics and chemistry	Agricultural chemistry
Genetics	Plant and animal genetics	Plant and animal breeding
Biology	Plant and animal pathology	Horticulture
Microbiology	Plant and animal physiology	Agronomy
Zoology	Nutrition	Veterinary medicine
Physics	Engineering	Mechanics
Atmospheric science	Climatology	Irrigation methods
Mathematics	Computer science	Computer software development
Economics	Applied economics	Farm management

General and pre-technology sciences are conducted primarily by universities and public research agencies. The products of this research are too general to be protected by intellectual property laws, and thus these activities attract little private-sector support. Technology invention is the product of both public and private research, and it in some cases public and private technology invention activities may overlap. Many public-sector technology inventions, however, are in fields where the products of research are not marketable and there is inadequate incentive for private invention (Huffman and Evenson, 1993, pp. 42-3).

Federal Support for Intramural versus Extramural Research

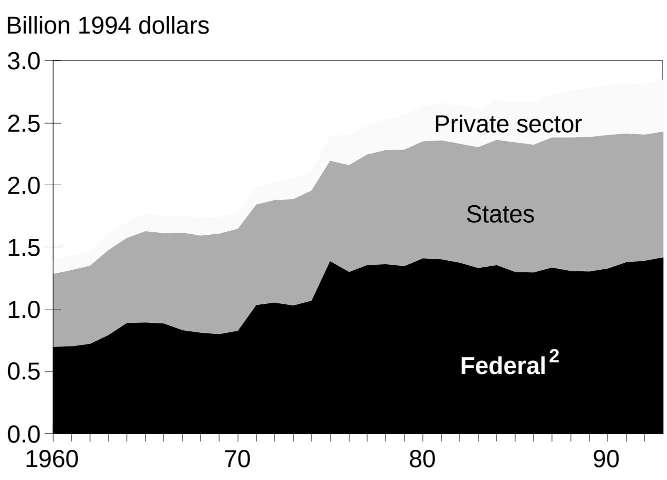
Intramural research (USDA)	**Extramural research** (State agricultural experiment stations and other cooperating institutions)
USDA's intramural research agencies include the: ***Agricultural Research Service (ARS)*** ❖ Accounts for about 70 percent of USDA appropriations for intramural research ❖ The workforce is 8,200 full-time equivalents (FTE's), including some 2,600 scientists ***Economic Research Service (ERS)*** ***Forest Service (FS)***	Most extramural agricultural research grants are administered by USDA's Cooperative State Research, Education, and Extension Service (CSREES), which also administers education and extension grants to State institutions. State agricultural experiment stations (SAES's) conduct most extramural agricultural research. SAES scientists are typically members of academic departments of land-grant universities, especially the colleges of agriculture. ❖ SAES staff includes about 24,000 professional and other staff (FTEs), including 6,400 scientist years. Research at forestry and veterinary medicine schools and colleges is also supported by CSREES-administered grants. These programs are also typically at land-grant universities. CSREES-administered grants also support the agricultural research programs of the historically black "1890" land-grant colleges.
Arguments in support: ❖ Provides in-house science expertise, essential for national and international leadership and coordination in agricultural science. ❖ Takes on higher-risk and long-term research, like plant and animal genome programs and global environmental change. ❖ Addresses national and regional research problems where State investment incentives may be low but social payoffs are potentially high, like food safety and diet and health. ❖ Maintains research infrastructure and laboratory capacity that is too expensive for individual States, such as hydrology labs and germplasm operations. ❖ Supports research needs of regulatory agencies, such as APHIS, FSIS, and FGIS, and the development of science-based regulations and policy. ❖ Collaborates in multinational agricultural research partnerships, like germplasm preservation. ❖ Facilitates technology transfer and commercialization by initiating and coordinating government/industry/university consortia.	***Arguments in support:*** ❖ Responds to State and local constituents and addresses specific agroclimatic needs. ❖ Federal grants underwrite and encourage State investments in university research. ❖ Has links to universities' nonagricultural basic and applied research programs. ❖ Federal grants support top scientists and researchers at universities. ❖ Extramural research grants support graduate students and thus human capital development in science. ❖ Research conducted at universities provides frontier material for classroom instruction and thus enhances education.

individual States or even regional programs. Food safety, nutrition and health, and germplasm preservation are examples of research issues for which there is a national rather than a State-specific or regional constituency. Federal regulatory agencies may particularly look to the intramural research agencies to provide the science base for the regulatory programs that protect the safety and health of the Nation's consumers.

Finding an administrative structure that would allow USDA's intramural science agencies to address these goals has provided a challenge to Federal research managers. For example, in 1972 USDA decentralized the research program management of USDA's Agricultural Research Service (ARS) from a national to a regional structure. To simplify further coordination with the SAES's, USDA organized ARS research programs around four regions. The reorganization was, however, not without controversy. Some observers felt that it compromised the ability of the USDA to provide national leadership in agricultural research (Office of Technology Assessment, 1981; Ruttan, 1983).

Public research expenditures rose by 3-4 percent per year in real terms up to around 1980, but since then, growth has slowed to 0.7 percent per year (fig. 4). To calculate real (inflation-adjusted) funding trends, annual expenditures are adjusted by a cost-of research index.

Figure 4
Federal, State, and private support for public agricultural research, 1960-94[1]



[1] Annual expenditures adjusted for inflation by cost-of-research deflator.
[2] Includes funds for USDA research agencies (Agricultural Research Service, Economic Research Service, and National Agricultural Library) and cooperative State research.
Source: Economic Research Service. Data derived from Alston and Pardey (1995).

Most of the post-1980 growth has come from increased contributions from the private sector, mainly for research conducted at land-grant universities. In real terms, Federal funding for agricultural research has been stagnant since 1976. State governments continued to increase their support for agricultural research until the economic recession of the early 1990's.

The ability of the public agricultural research system to respond to new demands is constrained by the slow growth in real funding and the substantial resources needed for maintenance research. Maintenance research is needed to offset the tendency of livestock and crop yields to fall over time, due to the emergence of resistant strains of pests and diseases. Requirements for maintenance research increase as agricultural productivity increases (Ruttan, 1983). Some estimates suggest that around 30 percent of agricultural research expenditures go to maintaining current yield levels (Adusei and Norton, 1990; Huffman and Evenson, 1993).

Setting the Research Agenda

Ruttan (1982) characterized the Federal-State agricultural research system as "articulate, decentralized, and undervalued" (p. 249). The institutional, or formula, funding approach established by the Hatch Act created a decentralized management structure. Decisions about allocating research resources were left largely to the States rather than to a central authority. The decentralized structure, with the combined research-extension role of the land-grant universities, enabled farm constituencies to express their needs directly to the scientific establishment. This established articulation among science-oriented research, technology-oriented research, and farm production. It served to direct research resources to commodities and production constraints important to the locality or State. According to Ruttan, these factors contributed to high economic returns to research. Because returns to research remained high, the system may have been undervalued, that is, the investment in public agricultural research may have been too small. The reasoning is that if an investment gives very high returns, its funding should be increased to the point where the return from the investment equals the opportunity cost of the funds. If agricultural research yields a higher return than other types of investment, shifting more funds to agricultural research would increase overall economic efficiency and growth.

While the system was effective in developing and delivering new technologies that increased farm productivity, it has been criticized for being slow to respond to the needs and expectations of other constituencies, such as consumers, nonfarm rural groups, and farm laborers. Internal and external evaluations of the system recommended changes in the way the system was managed and operated. To some extent these recommendations were carried out. Most noticeable is the changing nature of financial support for the system: the relative importance of institutional (formula) funding has fallen substantially, and support from the private sector has grown.

Criticisms of the Public Agricultural Research System

Despite the contribution of public agricultural research to agricultural productivity increases, the system came under increasing pressure during the 1960's and 1970's. Some critics charged that the agricultural research establishment was slow in responding to environmental, distributional, and humanitarian concerns. These critics sought to increase the attention given to such issues as environmental protection, natural resource conservation, human nutrition and health, rural development, the problems of hired workers, and animal welfare. Ruttan (1982) points to two books in particular that reflected this perspective. *Silent Spring*, by Rachel Carson, and *Hard Tomatoes, Hard Times*, by Jim Hightower, argued that agricultural research concentrated on a narrow set of goals and did not adequately address consumer, environmental, and rural issues. This sentiment led to political pressure for a broader research agenda that would address the concerns of these groups. In 1990, language introduced into the farm bill established broad goals for agricultural research under the heading of "sustainability" (see box, "Technology and Sustainability").

Recommendations for change also came from within the scientific community. In 1972 and 1982, two reports by independent scientific committees (National Research Council, 1972, *The Pound Report*; Rockefeller Foundation, 1982, *The Winrock Report*) faulted the system for placing too much emphasis on applied research on local problems and not enough on basic biological research. Both reports recommended greater competition for research funds (instead of formula-based funding) and a shift away from applied research to more basic biological research. The underlying rationale for these recommendations was that the breakthroughs needed to maintain historical rates of productivity growth in agriculture would be based on advances in basic biological sciences. These reports argued that applied research would not generate the needed breakthroughs because it tended to focus on the commodities and production constraints important to specific localities and States. However, these reports did not receive unanimous approval in the scientific community. *The Pound Report* in particular was criticized for applying evaluation criteria better suited to the basic sciences than to the applied work conducted by the USDA-SAES system. Defenders of the system contended that the standards used to judge agricultural research should put greater emphasis on technological innovation and productivity-enhancing activities rather than on bench science (Ruttan, 1987). Schuh (1986) argued that a narrow focus on basic research would undermine the mission orientation of the land-grant university, which is "to bridge the gap between society's current problems and the frontiers of knowledge" (p. 7).

In 1981, the Office of Technology Assessment (OTA) released a report called *An Assessment of the United States Food and Agricultural Research System*. The OTA report praised the accomplishments of public agricultural research and called for increased support of the Federal-State system. However, it also pointed to many weaknesses in the system. The report cited a lack of well-defined goals for food and agricultural research and judged the process for research priority setting as inadequate. According to OTA, decisions about allocating research resources were made "ad hoc" and coordination between different components of the system was insufficient. The report also found inequity among the States about who paid for and benefited from agricultural research; food-surplus States often spent more on agricultural research than food-deficient States did, although the latter were major beneficiaries of lower food costs. The OTA study recommended that research should be concentrated in areas that would generate large social benefits but that the private sector would be unlikely to find profitable. Also, the report noted the need to maintain a balance between site-specific research and basic biological research. The OTA recommended a stronger USDA research program on issues in the national interest while keeping a portion of the system decentralized. This would allow the States to facilitate applied agricultural research on local or regional issues.

In 1989, the National Research Council (NRC) recommended a major increase in the use of competitive grants to allocate agricultural research funds. The NRC concluded that agricultural research as a whole was underfunded. Therefore, an increase in competitive grants should come from new resources rather than from a diversion of existing resources (National Research Council, 1989b). While funding for the USDA's competitive grants program was increased in the 1990 farm bill, this growth was largely at the expense of formula funding.

Changing Sources of Support for the SAES's

Two factors have strongly influenced State agricultural experiment station funding: (1) an outgrowth of these criticisms and recommendations and (2) the need to secure new sources of funding. As a result, the nature of financial support for the State agricultural experiment stations has changed significantly over the past several

Technology and Sustainability

Several concerns have focused public attention on sustainable agriculture, including environmental degradation, natural resource conservation, food safety, and the viability of family farms and rural communities. For example, some production practices currently employed by farmers contribute to the erosion of environmental quality and to the depletion of the natural resource base. Sustainable technologies, on the other hand, are designed to mitigate the effect of agricultural production on the natural resource base and on the environment. The decision to adopt alternatives to conventional production technologies hinges upon the relative profitability of these alternatives. Accordingly, the public debate about sustainability is centered around the trade-offs between economic, environmental, and social consequences of adopting alternative production technologies.

In the United States, pressure from interest groups seeking to improve the well-being of farmworkers, rural communities, and the environment have ultimately influenced legislation pertaining to technologies adopted by producers. In particular, the 1990 farm bill explicitly dealt with sustainability issues in several ways. First, a specific definition of sustainability was adopted. According to this congressional definition, sustainable agriculture is an:

> "...integrated system of plant and animal production practices having a site-specific application that will, over the long term a) satisfy human food and fiber needs; b) enhance environmental quality; c) efficiently use non-renewable resources and on-farm resources and integrate appropriate natural biological cycles and controls; d) sustain the economic viability of farm operations; e) enhance the quality of life for farmers and society as a whole" (PL-95-113, 91 Stat. 981, 7USC 3101, Sec. 1404).

Second, the farm bill directed USDA to ensure that competitive grants awarded under the National Research Initiative (NRI) were consistent with the development of sustainable agricultural systems. Finally, the farm bill encouraged research designed to increase the knowledge and application of sustainable production systems. In particular, the Secretary of Agriculture is directed to conduct research and extension projects that reduce chemical use on farms, improve low-input farm management practices, and help crop and livestock enterprises.

USDA's research agencies shoulder the principal responsibility of carrying out the farm bill mandate to steer agriculture in a sustainable direction. To do this task more effectively, USDA formed a panel to develop a protocol for sustainable agriculture. This protocol could be applied to each NRI project to evaluate its relevance for promoting more sustainable agriculture. In this fashion, the protocol could serve to provide a quantitative measure of the contribution of research to sustainability.

Difficulties persist with the application of this protocol to an evaluation of NRI grant applications. These difficulties are in part due to the controversy surrounding definitional issues in sustainable agriculture. The idea of sustainability is believed to be subject to widely varying interpretations. Many alternatives to the congressional definition are available. For example, Ruttan (1992 and 1994) identifies three broad approaches to defining sustainability. One definition stresses the long-term capacity to supply a growing population with agricultural commodities at a reasonable cost to consumers. A second definition views sustainability as an ecological issue because agricultural commodity production can disrupt the ecological balance of natural systems, cause pollution, and deplete the stock of nonrenewable resources. The third definition emphasizes not only natural resources and the environment but also rural communities. According to this view, guided by such traditional values as stewardship and self-reliance, rural communities can be revitalized by adopting a holistic approach to both the physical and cultural dimensions of agricultural production.

A second difficulty associated with carrying out the protocol is the potential trade-off between different goals of sustainability. A research project may enhance one goal of sustainability (for example, profitability) while compromising another (for example, environment). As an example, recent research comparing farming systems in east-central South Dakota by Dobbs, Smolnik, and Mends (1991) found that sustainable technologies, while providing obvious environmental benefits, are unlikely to be as profitable as conventional technologies.

Finally, there is also the issue of evaluating projects with the potential to affect sustainability. The sustainability protocol assigns a score of zero to projects that have no direct, presumably short-term, effect on sustainable systems. Most basic research would fall into this category, although they have the potential to contribute to sustainability. Therefore, some NRI managers believe that the current scoring system is biased toward accepting projects showing immediate potential effects on the environment and the natural resource base (National Research Council, 1994). By implication, projects having a potential to yield benefits over the long term will be overlooked.

Despite the difficulties in implementing sustainable agriculture, proponents of sustainability believe that U.S. agricultural research is too narrowly focused on increasing production efficiency. They argue that in order for this research to be relevant, greater accommodation must be made to address the needs of a broader constituency, a new research agenda should address not only the profitability but also the environmental and social implications of alternative technologies used in agriculture.

years. Between 1978 and 1994, the share of the research budget for these institutions that came from State governments fell from 55.1 percent to 47.4 percent, while total Federal support (USDA and other Federal agencies combined) rose slightly, from 30.7 percent to 33.0 percent (table 1). This reversed a long-term trend in which State support for the SAES's had been increasing at a faster rate than Federal support. While USDA contributions to the SAES system fell from 22.2 percent to 20.3 percent, increased support from other Federal agencies more than made up the difference. The nongovernmental share of funding (industry grants, product sales, and other sources, combined) had the most rapid rate of growth. This funding source increased from 14.3 percent to 19.7 percent of total research expenditures at these institutions. Research grants from industry grew from 5.1 percent to 7.2 percent during this period.

The recent decline in the relative contribution of State governments to public agricultural research is partly a result of the 1990-91 economic recession. It may also be due to the decline in agriculture's share in local economies, the falling number of farms, and the resulting decline in the political influence of farm lobbies. Empirical studies on the political economy of public agricultural research in the United States showed that States with large agricultural sectors often allocate a larger portion of their State budget to agricultural research (Peterson, 1969; Guttman, 1978; Huffman and Miranowski, 1981; Rose-Ackerman and Evenson, 1983). These studies also found that farmers who organized more effectively for collective action (for example, more concentrated farm structure or membership in farm cooperatives) could increase public agricultural research funding by State governments. Because of agriculture's falling share of the economy and the declining number of farms, these studies were pessimistic about the future support from States for agricultural research unless new political constituencies could be developed.

Table 1—Sources of funding for State agricultural experiment stations, 1978 and 1994

Source	1978		1994	
	$1,000	*Percent*	*$1,000*	*Percent*
Governmental:				
State governments	374,933	55.1	1,010,861	47.4
USDA	150,977	22.2	432,993	20.3
Other agencies	57,856	8.5	270,016	12.7
Nongovernmental:				
Industry grants	34,704	5.1	152,898	7.2
Product sales	40,061	5.9	116,704	5.5
Other	22,407	3.3	148,226	7.0
Total	680,938	100.0	2,131,698	100.0

Note: Percentages may not sum to 100 due to rounding.
Source: Economic Research Service compiled from U.S. Department of Agriculture, *Inventory of Agricultural Research*.

While new sources of funding allow the public research to expand into new areas, the trend toward increased reliance on support from the private sector has generated concerns. 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 may give a grant to a university department if specified research is carried out. 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. According to the study, higher yielding varieties would have been more beneficial to livestock producers. The study also concluded that while both the public and private sectors gained from the joint research effort, the social cost of private assistance was high. This is because increased attention to yield would have had higher social benefits.

According to USDA's *Inventory of Agricultural Research*, nearly 25 percent of private funds going to State agricultural research institutions were designated for animal production research in 1992. Increased concentration in the livestock industry facilitates direct financial support of university and experiment station research on animal production. Another area where joint public-private support of research is employed is for research on new industrial uses of agricultural commodities. Support from the private sector is not always oriented toward developing new or lower cost products. In 1992, nonprofit foundations funded over half the research conducted by State agricultural research institutions on the causes of rural poverty, for example (USDA, 1992).

Another major change in the financial support of the system occurred in the administration of Federal funds for State research institutions. A principal recommendation of the Pound, Winrock, OTA, and NRC reports was that a greater share of Federal funds for agricultural research should be allocated competitively instead of as formula funds. Formula funds are unrestricted block grants given to State research institutions. Competitive grants, on the other hand, are awarded to individual scientists or research teams based on peer-reviewed project proposals. Projects are for a fixed term of usually 1 to 5 years. The USDA initiated a competitive grant program in 1978 and expanded it in the 1990 farm bill with the National Research Initiative. During the past several years, scientists at SAES institutions also became more active in competing for research grants administered by other Federal agencies, such as the National Science Foundation (NSF) and the National Institutes of Health (NIH).

Since the 1960's, the share of Federal agricultural research dollars administered as formula funds has declined significantly (table 2). In 1970, formula funds were 61 percent of all Federal research funds going to SAES and cooperating institutions, and 87 percent of USDA-administered funds. By 1994, formula funding had fallen to 30 percent of Federal funds and 49 percent of USDA funds for agricultural research at these institutions. Not all of the decline in formula funds was the result of the increased use of competitive grants, however. Noncompetitive project grants also grew substantially. In 1965, USDA began a "special grants" program, which allocated funds noncompetitively to specific research institutions for projects earmarked by Congress. The SAES institutions also receive research grants directly from USDA in-house research agencies in the form of cooperative agreements (contract research). ARS, the Forest Service, and the Economic Research Service use cooperative agreements to fund specific studies in support of their research programs.

The choice of a funding mechanism has significant implications on the character of agricultural research conducted in the State research system (see box, "Institutional versus Project Support of Agricultural Research"). Formula funding often encourages recipient institutions to undertake major mission-oriented applied research and technology development programs (Ruttan, 1982). It also relieves scientists from the burden of grant seeking, making more time available for research activities (Huffman and Just, 1994). Project support, on the other hand, encourages the research institute to become more responsive to the priorities established by the funding agency. It also enables USDA to draw upon the research capacity outside the land-grant university system (National Research Council, 1989b). According to a study by Frisvold and Day (1993), a larger share of competitive grants is allocated toward research on basic biology and animal production compared with other types of USDA funding mechanisms.[4] These are areas that are likely to generate new knowledge and technologies that can be applied nationally or regionally. Formula funds,

[4]This is partly due to the characteristics of competitive grant programs generally and partly due to how the NRI is designed. Congress mandated that NRI funds be allocated among six areas in the following proportions: plant systems (40 percent), animal systems (25 percent), natural resources (20 percent), nutrition (7 percent), processing (4 percent), and markets, trade, and rural development (4 percent).

Table 2—Federal support for State agricultural experiment stations

			Project support										
Year	USDA formula funds		USDA competitive grants		USDA special grants		USDA contracts and other[1]		Other Federal[2]		Total project support[3]		Total Federal support
	$1,000	*Pct.*	*$1,000*	*Pct.*	*$1,000*	*Pct.*	*$1,000*	*Pct.*	*$1,000*	*Pct.*	*$1,000*	*Pct.*	*$1,000*
1970	55,572	61	0	0	1,581	2	6,974	8	27,308	30	35,863	39	91,435
1975	80,948	58	0	0	10,448	8	11,686	8	35,300	26	57,434	42	138,382
1980	121,124	46	9,480	4	9,627	4	50,040	19	71,581	32	140,728	54	261,852
1985	188,232	51	11,514	3	20,395	6	36,847	10	112,414	31	181,170	49	369,402
1990	191,711	37	31,173	6	47,605	9	55,133	11	188,606	37	322,517	63	514,228
1992	209,400	35	40,057	7	61,914	10	65,981	11	221,315	37	389,267	65	598,667
1994	214,254	30	62,542	9	69,162	10	87,035	12	270,016	38	488,755	70	703,009
Gini[4]	0.34		0.63		0.59		0.55						
					0.51								

[1]Includes other research grants administered by CSREES (formally CSRS). [2]Including National Institutes of Health, National Science Foundation, U.S. Agency for International Development, Department of Defense, Department of Energy, National Aeronautics and Space Administration, Tennessee Valley Authority, Department of Health and Human Services, and other non-USDA agencies. This includes a mix of competitive and noncompetitive project grants. [3]May not add due to rounding. [4]Gini coefficients show the distribution of USDA funding among States (based on 1992 budget allocation).

Source: Economic Research Service compiled from U.S. Department of Agriculture, *Inventory of Agricultural Research*.

Institutional versus Project Support of Agricultural Research

The Federal Government supports both institutional and project funding of agricultural research. Historically, institutional support as unrestricted block grants to research institutions has been the primary form of Federal support for agricultural research. How these funds are used is left to the discretion of the receiving institutions. Project support for research, on the other hand, provides funds to individual researchers or teams for research on specific topics. Projects are for a fixed term of usually 1-5 years. Project funding by the USDA was initiated in 1965 with the Special Grants program and expanded in 1977 with the Competitive Grants Program.

Institutional support of research encourages research institutions to undertake major mission-oriented applied research programs. It also relieves researchers from the burden of grant seeking, freeing up more time for research activities. Project support, on the other hand, can encourage more fundamental, cutting-edge research and quickly focus research resources on newly emerging issues. Project funding also enables the USDA to draw upon research resources outside the land-grant system. Both systems of research support have merits, and the appropriate question for science policy is not whether one system of support is better than another, but what is the appropriate mix of the two systems for optimal research performance?

Federal Institutional Support for Agricultural Research

Formula funds. These are unrestricted block grants allocated to State agricultural experiment stations (SAES's) and cooperating institutions for research on agriculture, forestry, and veterinary medicine. Funds are allocated to States based on congressionally mandated formulas and administered by USDA's Cooperative State Research, Education, and Extension Service (CREES) in the following manner:

1. *Hatch Act of 1887*—supports agricultural research at SAES's;
2. *Evans-Allen Program* (Section 1455 of 1977 Farm Bill)—supports agricultural research at 1890 Colleges and Tuskegee University;
3. *McIntire-Stennis Act of 1962*—supports forestry research at the Forestry Colleges and SAES's;
4. *Animal Health and Disease Research Program* (Section 1433 of 1977 Farm Bill)—supports veterinary research at veterinary schools and SAES's.

Intramural research. Institutional support is also provided for research conducted at USDA research-performing agencies. These are primarily the Agricultural Research Service, Forest Service, and Economic Research Service.

Federal Project Support of Agricultural Research

The USDA and other Federal agencies also provide funds for specific projects of fixed terms.

USDA Competitive Grants. These grants are awarded on the basis of submitted research proposals that are peer-reviewed. Research proposals are considered for six broad categories: (1) natural resources and the environment; (2) nutrition, food quality, and health; (3) animal systems; (4) plant systems; (5) markets and trade; and (6) policy. Funds for the Competitive Grant Program were authorized by the National Research Initiative of the 1990 Farm Bill and are administered by CSREES.

USDA Special Grants. These grants are congressionally earmarked funds to specific universities or entities for specific research projects. Special Grants were first authorized in 1965 by P.L. 89-106, and are administered by CSREES.

Other USDA contracts, grants, and cooperative agreements. project support to SAES's from USDA research-performing agencies (Agricultural Research Service, Economic Research Service, and Forest Service).

Non-USDA federal grants for agricultural research. Several non-USDA Federal Agencies support agricultural research projects at State universities and research entities. These include the Department of Energy, Department of Defense, Department of Health and Human Services, National Institutes of Health, National Science Foundation, Tennessee Valley Authority, National Air and Space Agency, and the Agency for International Development.

special grants, and contract research, on the other hand, were more likely to support research for natural resource management, rural development, and for improving community services and the environment. Information and technology to address these issues are often more location-specific (Frisvold and Day, 1993).

Changes in funding mechanisms also affect the distribution of Federal funds among States. Competitive grants may favor States with strong basic sciences research at the expense of universities that emphasize applied technology development. Many States rely almost exclusively on formula funds for Federal support of agricultural research. Formula funds account for more than 70 percent of USDA research funds going to SAES's in 14 States and for more than 85 percent of funds in 5 States. California, on the other hand, receives most of its USDA research funds from a combination of competitive grants and contracts. Hawaii, North Dakota, and Massachusetts receive more than 40 percent of their USDA funds as special grants (Frisvold and Day, 1993). Buttel (1986) hypothesized that increased reliance on competitive grants might create a two-tier system of "haves" and "have-nots" within the land-grant university system. Frisvold and Day (1993) found that universities with highly ranked programs in basic biological sciences fared better than others in obtaining USDA competitive grants. They also found that formula funds were more equally distributed among States than project grants, as indicated by the smaller Gini coefficient associated with formula funds in table 2 (a Gini coefficient of zero would mean that each State receives an equal share of USDA research funds, while a value of 1.0 would mean that one State receives all research funds). Formula funds were more evenly distributed among States than project grants. This is especially true for the allocation of competitive grants and special grants, although these alternative funding mechanisms often offset each other. While the Gini coefficients for competitive grants and special grants are 0.63 and 0.59, respectively, the Gini coefficient for all project support is only 0.51 (table 2). In other words, a larger share of special grants went to States that received a smaller share of competitive grants. This tendency served to mitigate the distributional implications of increasing competitive funding.

Research Priorities for Public Agricultural Research

The increased reliance on project-oriented support for agricultural research in the Federal-State system places a greater burden for research management on the funding agencies. It shifts responsibility for priority setting from the experiment station to the funding agency. It also makes coordination between science-oriented research and technology-oriented research more problematic. Project-oriented research is less likely to be integrated into the programmatic themes established by an experiment station.

The growth in agricultural research conducted by the private sector also has important implications for public agricultural research. Research administrators in the public sector must increasingly justify their comparative advantage in conducting applied research compared with the private sector.

The USDA's Current Research Information System (CRIS) provides data about funding allocations for agricultural research in the Federal-State system. This system employs a four-way classification of agricultural research expenditures by commodity or resource, by field of science, by research problem area, and by activity. Each agricultural research project is assigned at least one classification code in each of these four areas. An annual USDA publication, the *Inventory of Agricultural Research*, gives the allocation of research expenditures and scientist-years by these classifications for Federal and State agricultural research institutions.

Allocation of Research Resources Between Programs and Goals

In 1992, more than $2.9 billion were spent on public agricultural research (table 3). Crop, livestock, and forestry research made up just more than 71 percent of total spending. Nearly 12 percent went for research on natural resource conservation and management, principally research on soil, water, and wildlife resources. The remaining 17 percent was distributed among four other program areas, including food science, general resources and technology, competition and trade, and research on rural people, communities and institutions.

Another indication of the goals of this research is given in figure 5. This figure shows the allocation of public research expenditures for each of the nine major research problem areas defined in CRIS for 1973, 1982, and 1992, in constant 1992 dollars. The share of research expenditures for these goals has remained stable during the past 20 years, with some minor changes. More than 70 percent of public agricultural research expenditures went to three goals: (1) reduction of production costs of food and forest products; (2) protection of forests, crops, and livestock from pests and diseases; and (3) conservation and management of natural resources. Research to protect agricultural products from pests and diseases increased in real terms and currently accounts for nearly a fourth of total agricultural research spending.

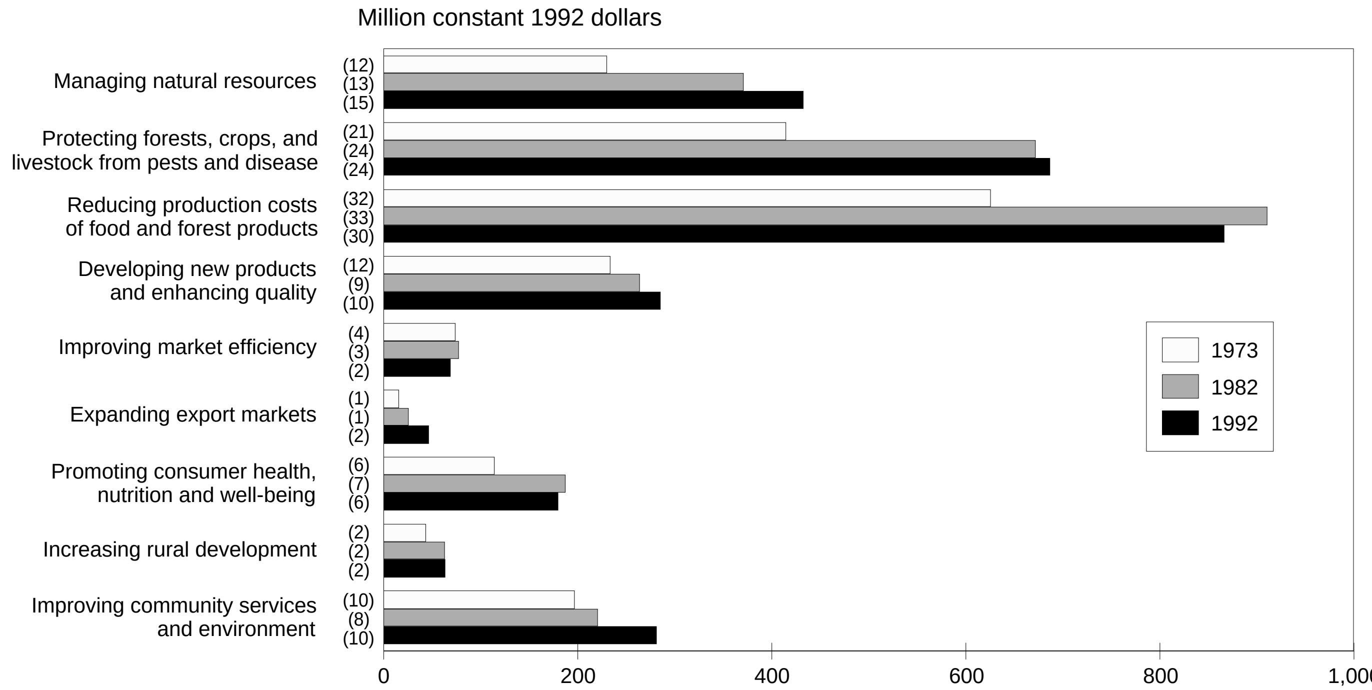
Table 3—Public research expenditures by program area, 1992

Research program area	Expenditure	Share of total
	$1,000	*Percent*
Crops	999,690	34.4
Animals	691,041	23.8
Forest resources	381,965	13.1
Natural resources	335,418	11.5
Food science and nutrition	169,302	5.8
Competition, trade, and adjustment	139,726	4.8
General resource and technology	100,310	3.5
People, communities and institutions	88,353	3.0
Unclassified	7,356	0.1
Total	2,913,161	100.0

Source: Economic Research Service compiled from U.S. Department of Agriculture, *Inventory of Agricultural Research.*

Figure 5

Allocation of USDA-SAES research expenditures, by goal[1]



Note: Percentage of annual total expenditures in parentheses. Totals may not sum due to rounding.

[1] Annual expenditures adjusted for inflation by cost-of-research deflator.

Source: Economic Research Service. Data derived from Alston and Pardey, 1995.

Research for natural resource management also experienced steady growth in real terms since 1973. Its share of the total budget increased from 12 percent in 1973 to 15 percent in 1992. On the other hand, research expenditures to reduce production costs declined in real terms between 1982 and 1992, falling from 33 percent to 30 percent of the total by 1992. The remaining 30 percent of research expenditures is allocated among the six remaining goals, which include post-harvest use, consumer and rural issues, and international development.[5]

[5] Other ways of broadly categorizing agricultural research expenditures have also been developed. The Joint Council for Food and Agricultural Sciences (JCFAS), which advises the USDA on research priorities, developed seven overall categories for allocating research expenditures. The Experiment Station Committee on Policy (ESCOP) uses a slightly different seven-category system and conducts an annual budget review and priority-setting exercise for the SAES's. These two systems correspond closely to the eight research program areas shown in table 3.

Economic Analysis of Research Resource Allocation[6]

The budget allocations of the public agricultural research shown in table 3 and figure 5 do not indicate whether too much or too little research is being allocated to any particular program area or goal. Measuring the allocative efficiency of these budget allocations requires expert opinion and analysis of technological possibilities and the potential economic and social impacts of new technology. Ruttan (1982) characterized the setting of agricultural research priorities as bringing information to bear on two principal questions:

(1) What are the possibilities of advancing knowledge or technology if resources are allocated to a particular commodity, problem, or discipline? and

(2) What will be the value to society of the new knowledge or the new technology if the research effort is successful?

[6] Alston, Norton, and Pardey (1995) present a comprehensive review of analytical models for allocating public resources for agricultural research. See also Ruttan (1982, pp. 262-97) and Fox (1987).

Scientists who are on the leading edge of a research discipline or problem being considered are probably best able to make judgments about the first question. The answer to the second question often requires information from economic or social sciences. Answers to these questions help identify what research should be given highest priority. Yet, they do not shed much light on whether the public or private sector should bear the primary responsibility for conducting this research. Increasingly, public agricultural research administrators need to pose a third question to their research allocation decisions:

(3) Of the research required to sustain productivity growth and meet other goals, what research will not be undertaken by the private sector?

The private sector will not conduct some kinds of research, while in other areas, the private sector is likely to underinvest. The rationale for public support of research is clearest for socially valuable research that the private sector does not find profitable to fund (see box, "Research on Public Goods"). Institutional linkages between public and private research can help assure that research efforts are not redundant and that new scientific knowledge is put to commercial use quickly (see "Public-Private Collaboration in Agricultural Research," p. 51, for a discussion of this issue).

Formal, analytical tools can help policymakers in allocating increasingly scarce research resources. These tools also serve to make public programs more accountable. At the same time, it is possible to overmanage a research system. Success in research is difficult to predict and innovation requires flexibility in order that scientific ingenuity is not stifled. Economic input into research planning and evaluation may be best conducted at the program level (that is, by commodities, disciplines,

Research on Public Goods

Several important areas of public concern have little commercial benefit to private researchers. Therefore, the public sector must conduct research to reach the level wanted by society as a whole.

Natural Resources and Environmental Research

Natural resources research covers the use, management, and conservation of natural resources and the environment. Natural resources research funded by USDA research agencies fell between 1978 and 1992, to $267 million. USDA in-house research in natural resources can be separated into six different topics: soil, land assessment and management, water, forest products, pollution, and other research (including interdisciplinary). Forest products research received the most funds in both 1978 and 1992. Soil research funding grew slightly over this period. The most dramatic increase was in the category "Other," specifically in interdisciplinary research, weather research, and remote sensing. Funds for water, land assessment, pollution, and forest products declined between 1978 and 1992.

Institutions outside the USDA are now conducting an increasing percentage of the natural resources and environmental research funded by the agency. Natural resource funding at SAES and cooperative institutions is spread relatively evenly among the different research topics. The category "Other" is the largest recipient of funds (with the leading research areas being "Interdisciplinary Research" and "Fish and Other Wildlife"). Forest Products received the next highest level of appropriations. Unlike USDA in-house research, the funding of each SAES research topic increased from 1978 to 1992 (to $465 million). State tax revenues were an increasingly important funding source for natural resources research at SAES.

Research on Food Safety, Nutrition, and Other Consumer Needs

One of the nine major goals of the public agricultural research system is to "protect consumer health and improve the nutrition and well-being of the American people" (CRIS, 1993). Research areas likely to be underfunded without public efforts are general nutrition research, research on contaminants, and various health hazards.

Most of USDA's in-house research focused on, in order of funding received in 1992, human nutrition, microbial contamination, and toxic contaminants. Research on human nutrition, microbial contaminants and natural toxins increased between 1978 and 1992. However, USDA research on consumer issues as a whole fell approximately 14 percent between 1978 and 1992 to less than $34 million (in real terms). Generally, USDA moved away from the broader areas of food-related research to focus on high-profile research with a larger public good component.

At SAES and other institutions, the priority patterns were similar to those at USDA, with nutrition, microbial, and toxic contaminant research receiving the most funding. However, funding for food-related research increased and the distribution of research funds was broader across other categories.

USDA appears to have reduced its role in consumer research overall, except microbial and human nutrition research. SAES and other institutions continued to play an increasing part in food and related research.

and broadly defined research problems) rather than by individual projects. Applying formal models of research allocation is also more difficult for non-commodity research, such as more basic research that cuts across several commodities and applied research that generates nonmarket benefits.

Benefit-cost analysis, or the "economic surplus" approach. Benefit-cost analysis compares the present value of the estimated research costs of a project or program to its anticipated benefits. It requires estimates of expected yield increases over time under various levels of research, expected adoption rates, and anticipated aggregate production and price effects. The advantage of this method is that a consistent measure of economic efficiency is applied to each alternative. In the last several years, significant progress has been made in laying the analytical foundation for doing cost/benefit analysis of research resource allocation (Alston, Norton, and Pardey, 1995).

There is a practical barrier to estimating detailed prospective rates of return. Scientists often have difficulty providing informed mean estimates of the effects of research on yield or productivity increases where the scientific outcome of the research is yet unknown. Doing this for basic research would be particularly difficult where the connection of the research to a specific future commercial application is less clear. Past attempts to estimate the broader effects of new technologies suggest the potential difficulties with this approach. For example, in retrospect, scientists appeared to have grossly overestimated the yield effects of bovine somatotropin (McClelland, Kuchler, and Reilly, 1991). After the product was near release, enough information was finally available to estimate yield changes. In fact, onfarm improvement in milk production efficiency is likely be less than 10 percent compared with early estimates of 30 percent or more. On the other hand, scientists may underestimate the effect of scientific and technological advances in other disciplines on their own research. This may lead them to understate the potential for technological breakthroughs. For example, plant breeders may be unable to assess the possibility of advances in plant genetics, although these advances are likely to significantly affect the productivity of their own research.

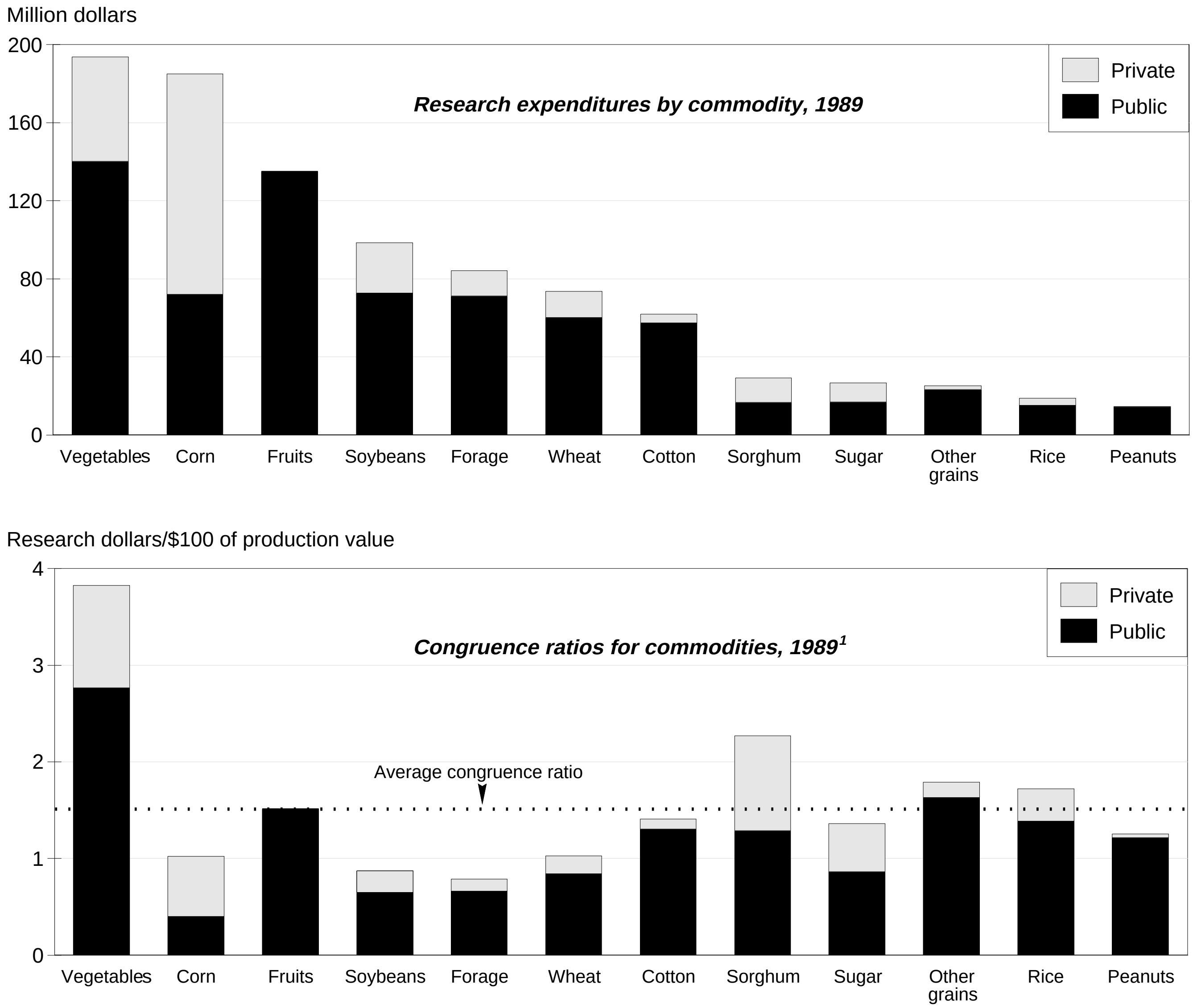
Estimates of the rate of return to research as a guide to funding. An approach that avoids the problem of eliciting prospective evaluations of proposed research projects is to base current research allocation on estimated rates of return to past research. Rate of return estimates can provide insights into the amount of resources that should be allocated to research, how these resources should be allocated among program areas, and who should fund different kinds of research (see "Economic Returns to Public Agricultural Research," p. 24, and the Appendix for detailed discussions of this issue). The approach seems to suggest very broad resource allocation (for example, basic versus applied research and livestock versus crop research). However, at a more disaggregated level there is a large degree of variability and uncertainty in these estimates.

Congruence models. A simple but somewhat naive approach for evaluating the allocation of research expenditures is the congruence model (also called the parity model). The congruence model compares research expenditures with the economic importance of a particular commodity, resource, production stage, or region. It is most often employed by comparing research expenditures among agricultural commodities. Congruence implies that each commodity receives the same level of research funding as a percentage of either the commodity's gross value of production or value-added. The parity idea is based on two assumptions: that the possibilities for technological advance for a given level of research are the same for all commodities; and that the value of a scientific or technical innovation is proportional to the value of the commodity. While both assumptions are simplistic, the congruence model represents a useful starting point for assessing the allocation of research resource. It is a straightforward way to use economic data to put research expenditures into perspective. According to Ruttan (1982), departures from parity should be based on explicit rationale. Such rationales might be the extent to which the private sector can support research in a commodity, judgments about differences in technological opportunities, and objectives other than economic efficiency.

In 1989, an average of $13.00 was spent on research for each $1,000 of production (congruence ratio) of 12 selected commodities: vegetables, corn, fruits, soybean, forage, wheat, cotton, sorghum, sugar, other grains, rice, and peanuts (fig. 6). Private seed companies conducted a large share of research for corn, sorghum, sugar, and vegetables.[7] If only public expenditures are taken into account, the congruence ratio for corn is far lower than for the other 11 commodities. Once private expenditures are added, however, corn research is much closer to the average congruence ratio. On the other hand, congru-

[7]The estimates for private plant-breeding expenditures are derived from a survey conducted by Kalton, Richardson, and Frey (1989). See table 17 for more detailed information from this survey. While the estimates for private research include only plant breeding, this is one field of science where public and private research are likely to overlap. Around 70 to 80 percent of public research on crop commodities is for increasing biological efficiency and crop protection (Huffman and Evenson, 1993).

Figure 6
Congruence of commodity research



[1] Congruence ratios are one way of comparing research spending among commodities. The congruence ratio is the amount spent on research as a percentage of the value of production for a commodity. For example, of the commodities shown in this figure, research spending equals 1.5 percent of the value of production on average (average congruence ratio). For vegetables, research spending is almost 4 percent of production value. For corn, soybeans, forage, and wheat, research spending is at or below 1 percent of production value.

Sources: Economic Research Service. Data for public research expenditures derived from USDA, *Inventory of Agricultural Research* private plant breeding data derived from Kalton, Richardson, and Frey (1989).

ence ratios for sorghum, and to a lesser extent, rice, exceed the average once the level of private research for these crops is included.

The congruence model is limited as an allocation tool since it fails to include the timing of research benefits and costs, discount rates, probable adoption patterns, technological opportunities, and market characteristics of different commodities. Nor does it take into account possible economies of scale or diminishing returns in research. There is a minimum size needed for a commodity research program to be viable. This may explain why the congruence ratios for groups of commodities, like vegetables and fruits, are higher than those for single commodities. Each fruit and vegetable crop will need a research program, which must meet a certain minimum size to be effective. Also, once a certain level of funding is reached, the potential value of additional research (that is, opportunities at the margin) may be diminished. For example, while the congruence ratios for corn and soybeans are below average, gross research funding for these crops is quite large.

Scoring models. Agricultural policy is concerned not only with enhancing production efficiency but also with equity, environmental protection, and the quality of rural life. Scoring models attempt to take into account a broader set of objectives for agricultural research. A research agency or governing committee first develops a set of criteria for measuring research objectives and gives each criterion a weight according to its relative importance. A panel of reviewers then scores each proposed project or program based on each criterion. These scores provide a ranking for the set of possible research resource allocations. The drawbacks of the scoring approach include the following: the expense of participation in the review panel, ranking subjectivity (real or perceived), and the lack of measures to weed out redundancy. Outcomes are determined by how much weight is given to each goal. When used in isolation from other methods, scoring exercises have generally been unsatisfactory. In practice, scoring has been more useful when combined with benefit/cost analysis. For example, if both equity and efficiency are stated as goals for research, then the use of benefit/cost analysis can determine how much economic efficiency might have to be given up to attain a desired distribution of research benefits.

Policy Implications

The rate of growth in public funding for agricultural research has significantly slowed since the mid-1970's. Furthermore, considerable resources are devoted to simply maintaining current productivity levels. These factors constrain the ability of the public agricultural research system to respond to a broadening set of societal demands concerning agricultural and food technology. State institutions are relying more heavily on the private sector for new sources of funding. Private contributions could exert a disproportionate influence on the research agenda of public institutions.

Federal support for agricultural research at land-grant universities and SAES's is undergoing significant institutional change. Federal funds have moved away from the traditional block grant (formula-funding) system to project-based support. Formula funds account for less than a third of all Federal funds for agricultural research at State institutions, and about a half of the extramural research funds administered by the USDA. Project-based support may be in the form of competitive or noncompetitive grants. Competitive grants are often allocated less equally among States than are formula funds, with a larger share going to universities with the strongest basic research programs in biological sciences. However, the allocation of noncompetitive, congressionally earmarked grants generally counterbalances the distribution of competitive grants. Increased reliance on project-based funding may reduce a research institute's ability to undertake major mission-oriented applied research. It also diverts scientific resources away from research to grant-seeking activities. On the other hand, the use of competitive research grants enables the Federal Government to draw upon research resources outside the land-grant university system. This may encourage more fundamental, cutting-edge research for agriculture.

Increasingly scarce resources for public agricultural research place a greater burden on research administrators to allocate research resources to high-priority areas. They must carefully assess public versus private—and Federal versus State—responsibilities in science and technology development. Economic cost-benefit analysis can be a useful tool for identifying high-payoff areas, although assessing non-market benefits from research is more problematic.