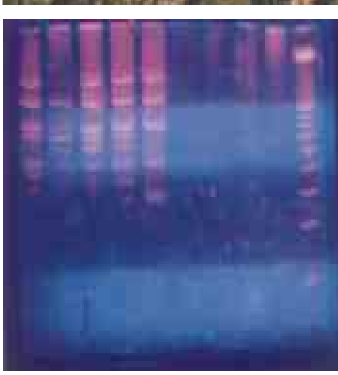
POLICY PAPER 16

The Funding and Organization of Agricultural Research in India: Evolution and Emerging Policy Issues



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Policy Paper 16

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The Funding and Organization of Agricultural Research in India: Evolution and Emerging Policy Issues

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Foreword

The Indian agricultural research system has a long history of organized research efforts with significant impact on food security and poverty alleviation. But it now needs innovations in organization and management of research to keep pace with developments in science, economic reforms, funding constraints and other global changes. These developments are expected to have significant impact on research challenges, organization of research efforts, resource sharing, management of intellectual property, etc. An objective analysis, collective wisdom, past experiences, and innovative and successful initiatives taken by the others must guide such a paradigm shift for greater effectiveness and efficiency of the system.

This Centre accords high priority to the analysis of research policy and contributed to the debate on it in the past. The present work provides new insights into the contemporary developments and emerging policy issues. An attempt is made to analyze funding and provision of research separately, and to look into effective funding mechanisms. Resource allocation, accountability and research impact are also dealt with an objective that these issues are going to be much more critical in future. Ecoregional research approach, biotechnology-related issues, human resource development, management reforms, and private research are other highlights of the present work.

Nature and extent of donors' support to the Indian system, and intensity of research efforts in India vis-à-vis other countries are revealing in themselves. Contemporary developments in international research organizations and other national research systems and public organizations and their implications for the Indian system are brought up-front. The idea is to learn from these experiences and evolve a strategy of policy, organizational, management and regulatory reforms for addressing the emerging challenges efficiently and become not only locally relevant but also globally competitive. A good deal of collaborative efforts is made to put the emerging issues into perspectives with adequate information and analysis. I hope that as in the past policy makers, researchers and research managers would find this work useful.

January 2003

Mruthyunjaya
Director
National Centre for
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and Policy Research

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Authors

Acronyms

AgGDP	Agricultural gross domestic product
AHRD	Agricultural human resource development
AICRP	All India Coordinated Research Project
CARP	Competitive Agricultural Research Program
CGP	Competitive Grant Program
DARE	Department of Agricultural Research and Education
DBT	Department of Biotechnology
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
GDP	Gross domestic product
GMOs	Genetically modified organisms
GoI	Government of India
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IFPRI	International Food Policy Research Institute
KVKs	*Krishi Vigyan Kendras*
NARP	National Agricultural Research Project
NARS	National agricultural research system
NATP	National Agricultural Technology Project
NGOs	Non-governmental organizations
NRCs	National Research Centres
PPP	Purchasing power parity
R&D	Research and development
R&E	Research and education
RCGM	Review Committee on Genetic Manipulation
SAUs	State agricultural universities
UPCAR	Uttar Pradesh Council of Agricultural Research
USA	United States of America
USAID	United States Agency for International Development

Executive Summary

This report examines trends in sourcing and allocation of public funds to providers of agricultural research services in India over the past three decades. The paper also discusses the emerging policy issues for agricultural research in India in light of the increasing role of markets, growing participation of the private sector in research, rapid advances in science, and strengthening of intellectual property rights. The need for change also stems from the fact that the Indian system has now reached a stage where it must address 'second generation problems' relating to organizational rigidities, inefficiencies, and difficulties in sustaining funding.

Funding of research

Sources and allocation of funds. The central government provides 52% of public funding for agricultural research and education (R&E) in India, which almost entirely passes through the Indian Council of Agricultural Research (ICAR). A significant proportion of the funds allocated to the ICAR (30%) is made available to other research providers, mainly the state agricultural universities (SAUs), with small amounts going to public research institutions outside the agricultural sector and to private research organizations (for profit and non-profit). About 30% of this extramural funding from ICAR is made through the All India Coordinated Research Projects (AICRPs) in the form of block grants, 12% through competitive funding schemes, 17% through grant to district outreach centers, the *Krishi Vigyan Kendras*, and the rest as donor-funded and development grants to SAUs.

The second major source of funding for agricultural research in India is annual block grants from the state governments to the SAUs which accounts for a further 43% of all research funds. In terms of spending, all ICAR institutes together accounted for 37% of the national expenditure on agricultural R&E, SAUs for 51%, and the remaining 12% was spent by other public and private organizations.

Trends in funding. India has consistently committed substantial government funds for research in all fields of science, including agriculture. Total funding for agricultural R&E increased ten fold in real terms from 1961 to reach Rs 25.0 billion in 1999 prices (or $2,893 million 1999 international dollars) in 2000. Using simplistic assumptions, nearly three-fourths was estimated to be spent on 'research' (net of education).

Overall public research funding for agriculture grew at 3.2% in the 1970s, 7.0% in the 1980s, and slowed to 4.6% in the 1990s. Funding from the states grew rapidly during the 1960s because a large number of SAUs were established during this period. Central funding has outpaced state funding thereafter and their shares became almost equal in the 1980s and the 1990s.

International perspectives on funding. Although India has one of the largest research systems in the world, the public sector still under-invests relative to other developing countries. In the late 1990s, India invested 0.31% of AgGDP in agricultural research, close to China at 0.43%, but significantly lower than the average for all developing countries of 0.62%. Industrialized countries spent a much higher figure—2.64% of AgGDP—on agricultural research. However, the growth rate of spending has been higher in India than for developing countries as a whole. Spending has accelerated through the 1990s, in contrast with a worldwide slowdown and even decline in some countries. If India can continue this trend, research intensity should reach the average for all developing countries in the next few years.

Funding by states. The intensity of state funding has increased in all states but there is wide variation in the intensity between states. The states of Himachal Pradesh, Tamil Nadu, Haryana, Maharashtra, Gujarat and Kerala, have comparatively high ratios (over 0.4% of Agricultural Gross Domestic Product or AgGDP) while the states of Madhya Pradesh, Rajasthan, Uttar Pradesh and West Bengal had very low ratios (less than 0.2% of AgGDP). Studies have found that per capita state funding is strongly and positively related to per capita AgGDP. Rural literacy and the share of agriculture in government expenditure also had a positive and significant effect on research intensity.

Private research funding. Total private or business funding for agricultural research (including funding by state-owned enterprises) in India doubled from 1985 to reach Rs 1,695 million (US$ 51 million) in 1995, or 11% of total agricultural research funding. Private research funding has grown at 7.5% annually compared to 5.1% in the public sector over the same period.

The largest private investment occurs in pesticides and food processing, followed by seed, fertilizer, and machinery. The most rapid increases in private growth have occurred in food processing, seeds, veterinary products, and sugar. More recently, there has also been strong investment in biotechnology, animal health and the poultry sector. This has been accompanied by significant growth in research expenditure by multinational companies.

Donor funding. Donors have played a key role in the development of the Indian agricultural research system. The two largest donors, the United States Agency for International Development (USAID) and the World Bank contributed some $US 646 million over the past four decades. From 1960 to 1977 USAID supported building of the SAUs, followed by other projects including a major agricultural research project in the 1980s when its support peaked and then ceased around 1990. Beginning in 1980, the World Bank became a significant supporter of agricultural research, first at the state and zonal levels, and from 1997 at the national level.

Donor support to agricultural research has helped to increase intensity levels. However, long-run funding sustainability requires that India give high priority to agricultural research investment over non-developmental expenditures many of which are subsidies. This is particularly so when the rates of returns to agricultural research are found to be very attractive.

Resource allocation. When actual research expenditure in different ecoregions was compared with the normative allocation using the congruence rule (value of production modified by criteria for sustainability and equity), it was found that contrary to general belief, less-favored environments received slightly more resources than justified by the congruence rule. In ICAR, crop research received the highest proportion of research expenditure followed by animal sciences and natural resource management. Allocations are broadly in line with the congruence rule, although both livestock and horticulture are high growth sub-sectors that might justify slightly more resources than indicated by value of production.

Human resources for R&E

The number of scientists in ICAR in 1998 was 4,092 and has remained steady since the 1980s. The number of scientists in the SAUs was 17,678 in 1992, a sharp drop from the 1980s. The number in SAUs has likely further depleted in the 1990s, because of non-replacement of retiring faculty and restrictions on recruitment. Adjusting the number of scientists by share of research expenditure relative to extension and education (for ICAR) and percent time spent on research (for SAUs), the number of full-time scientists in research in the 1990s was 2,999 in ICAR and 8,132 in SAUs, giving a total of 11,131 full-time researchers in the country—a figure similar to that in the USA.

The educational qualification of Indian researchers is also impressive—more than two-thirds of researchers hold a Ph. D. degree and the rest are MS holders. The proportion of women researchers is, however, very low—7.5% in ICAR and 2.1% in the SAUs.

Impacts of research

Many studies have empirically examined the economic impact of agricultural research in India. Although there is considerable variation, the average return to investment was about 70%, with a median value in excess of 50%. These studies have also shown that the return has not declined since the Green Revolution and that returns to public research investments have been higher than those for public extension or private research. Although these rates of return provide a convincing case for enhancing public funding to agricultural research, high aggregate rates of return may hide considerable inefficiencies in the system. For example, one study found that although the rate of return to wheat improvement research in India over the period, 1978-1991 was estimated to be 55% in aggregate, eight programs had a negative rate of return when spillins were taken into account.

Emerging policy issues

Balancing multiple research objectives. The Indian research system is struggling to balance among multiple objectives, ranging from traditional food security objectives, to emerging demands to serve a more market oriented economy, meet the needs of more sophisticated consumers, and preserve the environment. Striking a balance between these objectives has major implications for organization of research and prioritization of the research agenda. Also, public research institutions must work closely with key stakeholders to define priorities that address multiple objectives, employing formal research prioritization approaches. This is extremely important when the system is large in size, objectives are conflicting and clients are poor in articulating their research needs.

Center versus state roles. Agricultural research is more centralized in India relative to other large countries, such as the USA, since a higher share of federal funding in the USA is transferred to the states. Conceptually, SAUs should have primary responsibility for applied and adaptive research to meet local demands in their respective states, and ICAR should take the lead in strategic and some applied research that is relevant to several states in order to generate spillovers to enhance efficiency in state research programs. In some research areas, especially crop breeding, spillovers are pervasive. The AICRPs provide a mechanism for facilitating such spillovers. Studies showed that spillovers from the wheat research program of IARI accounted for a large share of benefits of wheat breeding research in India in the post-Green Revolution period.

However, a shortage of funding in the SAUs has had adverse effects on human resources development, research infrastructure, and linkages with farmers, and ICAR continues to provide much of the applied research agenda. There is an urgent need to sensitize policy makers at the state level to the payoffs to investing in research. At the same time, the central government might develop a funding formula that supports the weaker states, but provides incentives to stronger states to increase their funding (e.g., matching grants).

Toward a more pluralistic system. ICAR recognizes that the national agricultural research system is a pluralistic system of research providers in which the comparative advantages of each must be considered as well as innovative partnerships to exploit complimentarity. However, effective implementation of this policy needs greater awareness across the system. In particular, the growing role of private research and its implications for public institutions are not widely appreciated. Where the private sector can efficiently provide near-market research services, the public sector should be prepared to withdraw and play a complementary role. Enabling institutional mechanisms, especially protection of intellectual property rights (IPRs) and capacity within the public sector to manage partnerships, can help develop and sustain appropriate linkages with the private sector.

Sustainability of research funding. Increased funding has not matched the continuing expansion of the number of research institutions and the wider agenda, resulting in a steady increase in the share of salary and overhead expenditures at the expense of operating expenditures. Although competitive funding has increased operating budgets for some, it still accounts for a low share of total funding. To enhance accountability, quality and efficiency of the system, a higher share of funds should be gradually shifted to competitive funding. However, regular block grants must continue in order to maintain and upgrade research infrastructure and human resources, and strengthen basic and strategic research.

New resource generation opportunities such as payments for services by farmers growing high value crops (commercial livestock and fruit crops), income generation through commercialization of technology and services, and contract research with the private sector are emerging and must be tapped. ICAR has set a target of 25% of budget share from these sources by 2020 that will require development of capacities in IPRs and business skills.

Challenges of modern science. Although India has developed relatively good capacity in new areas of science, especially biotechnology, these have raised a number of challenges—development of research capacity, biosafety and IPR regulations, and management of public dialogue on controversial issues. It is expected that the private sector will be an active player in biotechnology in India, the public sector will have to play a dominant role, especially for non-commercial agriculture. Also, given the number of public and private institutions involved, there is much potential for forging public-private linkages to enhance overall impacts.

Given the current debate on biotechnology in India and elsewhere, effective biosafety regulations must be in place that are credible, cost-effective and properly coordinated. This is the single major constraint to application of transgenic technology in India, which still has only just released the first product (Bt cotton), despite many years of research and many products in the pipeline. Finally a dimension often neglected is the provision of information about these new technologies to farmers.

Organization and management reforms. The public sector in general in India suffers from centralization and bureaucratization that imposes high transaction costs at all levels. Although ICAR recognizes these problems and has initiated a number of organizational and management reforms, there are still important gaps as well as problems in their implementation. Institutional rigidities imposed by commodity and disciplinary boundaries restrict the flow of information between hierarchies and organizations in a large system such as India's. Proliferation of research programs has meant that many programs serving small states and agro-ecological zones are inefficient. Much remains to be done to decentralize and devolve power so that transaction costs can be reduced to acceptable levels for efficient research management. Resource allocation needs to be linked to research planning based on 'bottom up' approaches involving relevant stakeholders and feedback from monitoring and impact assessment. Implementation of such processes has been attempted several times, albeit with varying degrees of success.

Finally, although successive review panels of ICAR have recommended changes, past attempts at reform failed due to lack of financial flexibility and autonomy of ICAR. Support of high level policy makers at both the central government and state government levels is needed to implement this far reaching reform agenda.

Development of human resources. There is a growing problem in the quality of scientific human resources owing to inbreeding in the system, especially in the SAU system, professional isolation and weakening of global scientific linkages. This trend must be arrested through assessment of human resource needs and use of foreign grants and loans for human resources development, and to support participation in international scientific networks and other initiatives. At the same time, performance-based evaluation of scientists that is linked with incentives and the reward system is long overdue.

Technology transfer. It is generally agreed that payoffs to agricultural research could be much higher with a stronger research-extension interface. Most scientists lack skills and incentives to assess farmers' research needs and design appropriate technologies, as well as operating expenses for on-farm research. In addition, supply-driven extension approaches focused on the public sector in India are overdue for drastic overhaul. Improved accountability to clients through incentive systems in the research system and piloting of more pluralistic and demand-driven extension systems are now being given higher priority as a way to speed technology transfer.

Summing up

The Indian research system is facing new demands. Even with a rapidly expanding private sector in agricultural research, the public sector will continue to play a dominant role for many years to come. A strong central research system is still required but the role of this system must evolve to focus on upstream and strategic research to generate spillovers at the national level. Other actors will play an increasing role in the system, especially the SAUs, general science research institutes, and the private sector. The articulation of actors in this more institutional diverse and decentralized NARS is evolving. Inevitably there will be tensions that must be resolved, such as the effort to organize research along agro-ecological lines to enhance efficiency, while at the same time attempting to attract funding at the local level within the context of politically-defined administrative boundaries.

The efficiency and effectiveness of the public sector will depend on critical policy changes and institutional and management reforms to drastically improve its performance. These reforms must evolve around autonomy, decentralization, financial flexibility, and accountability. There must be greater realization at the policy level of the need for reform in order to keep pace with global changes. The public research system itself also requires an internal paradigm shift that links funding to performance of research providers, improves relevance of research through participatory approaches, and institutes a performance-based incentives and reward system.

1. Introduction

India has one of the largest and most complex agricultural research systems in the world with over a century of organized application of science to agriculture. A proactive policy by the government toward agricultural research and education (R&E), [1] coupled with support from a number of bilateral and multilateral donors has produced an institutionally diverse research system that has achieved many successes, most notably the Green Revolution in the 1960s and 1970s. The country is not only self-sufficient in food, but also commands a strong position in world markets for some commodities. Many studies have empirically shown impressive performance of the system with annual rates of return to investment in research ranging from 35 to 155% (Evenson et al. 1999). Notwithstanding these achievements, the system must now address a more complex and expanding research agenda of sustaining natural resources, enhancing product quality and ensuring food safety, besides continued emphasis on increasing household food and nutritional security and reducing poverty. These new challenges require a re-matching of needs with resources, and a reorientation of R&E policy.

The reorientation of R&E policy and strategy must be in tune with developments taking place at the national and international levels. The increasing role of markets, growing participation of the private sector in research, rapid advances in science, and strengthening of intellectual property rights have a significant bearing on the organization and management of agricultural research. The need for change also stems from the fact that the Indian system has now reached a stage where it must address 'second generation problems' relating to organizational rigidities, inefficiencies, and difficulties in sustaining funding. These issues are

[1] In India, agricultural research and education are mainly carried out in the same institutions and are treated together in most of this paper. In addition, agricultural research also includes some frontline extension, which is the integrated mandate of the national agricultural research system. Further, in this paper agricultural research includes research on crops, livestock, fruits, plantation crops, fisheries and agro-forestry but not forestry for which there is a separate research system.

particularly important in an era of a liberalizing economy, India's entry into the World Trade Organization (WTO), and tightening of the public purse.

Against this background, this policy paper reviews the funding and organization of agricultural R&E in India. After presenting the macro-economic and sectoral policy context for agricultural development in India, the chapter reviews the historical evolution of R&E policies and institutions and summarizes the current situation. The following section summarizes sources of, and trends, in public funding, human resources, and allocation of funds to providers of research services. The paper concludes with a discussion of the emerging policy issues for agricultural R&E in India at the beginning of the new millennium.

2. The Context

The macro-economic environment

Following independence, India pursued a socialistic development path emphasizing heavy industry, import substitution, high levels of protection of domestic industry, public sector regulation, and public investment. Allocation of capital and foreign exchange was controlled through a highly bureaucratic system of licenses and permits, leading to what was termed the 'license Raj' (Das 2001). Although this strategy created a massive industrial base and infrastructure in the pubic sector, it could only generate a modest economic growth rate (around 3.5% per annum) in the first three decades after Independence.

By 1991, a mounting balance of payment deficit forced the government to implement drastic economy-wide reforms. These reforms liberalized imports by dismantling the quota system and cutting tariffs, reduced the fiscal deficit, deregulated most industries, and openly solicited private investment (including foreign direct investment). The reforms were further reinforced by India's commitments (as a founding member) to the WTO. A second phase of reform covering the financial sector, public sector organizations, strengthening of intellectual property rights, and labor regulations, has recently been initiated. As a result of the reform program, economic growth accelerated to over 6% annually in the 1990s, the economy became more export oriented, and the incidence of poverty declined significantly.

Economic reform was not targeted at agriculture, and in fact liberalization of the agricultural sector has lagged most other sectors. However, agricultural exports increased significantly and there was greater participation of the private sector in agricultural input industries, such as the seed industry. Also, the rate of private capital formation in agriculture accelerated owing to improvement in the terms of trade. Public investment in infrastructure and R&E, interventions in food grain markets aimed at enhancing national food security, and various public programs for conservation of natural resources and poverty reduction continued as high priority areas for government support. Subsidies on agricultural inputs, especially water, electricity, fertilizer, and food marketing and distribution continued at high levels to reach 7% of agricultural gross domestic product (AgGDP) (Gulati and Sharma 1995). However, it is expected that the policy of market-led development will be extended to the agricultural sector, adding urgency to the need to clearly define the role of the state, enhance the efficiency of state interventions, and promote partnerships with the private sector.

Agricultural development: issues and policies

Indian agriculture is highly diversified both in terms of production environments and activities. Small farmers (less than 2 ha) constitute about 80% of total farm holdings and occupy 40% of agricultural land. Despite a rapid increase in livestock production, the crop sector still contributes three-fourths to the total value of agricultural output. Agricultural growth registered a sharp jump in the late 1960s and 1970s as a result of the widespread adoption of the new seed-fertilizer-based Green Revolution technology for rice and wheat in irrigated areas. This growth spread to rainfed areas from the 1980s with the adoption of hybrid seeds of maize, sorghum, pearl millet and cotton, although the impacts were less widespread and many areas with harsh conditions continue to experience low and unstable production. Average crop yields have increased by an average of 1.6 percent annually over the past three decades as a result of a marked increase in irrigated area, use of modern inputs especially fertilizer, and increased cropping intensity. Yield growth and increased cropping intensity resulted in impressive growth in agricultural production, despite virtually no increase in cultivated area. Since 1980, these trends have been echoed in the livestock sector, which has grown even faster at 5 percent annually, due to rapid growth in milk, poultry and fish production.

Empirical studies have shown that non-price factors, particularly irrigation, land reform, infrastructural development and technical change were the main sources of agricultural growth (Desai 1997; Fan et al. 1999). Estimates of total factor productivity (TFP) growth for Indian agriculture since the Green Revolution average 1.5-2.0 percent annually, in line with growth in industrialized countries (Pingali and Heisey, 2000; Murgai, 2000). In addition, the contribution of TFP to output growth has become more

Table 1. Trends in input use, yields and production in Indian agriculture

Indicator	**1961**	**1971**	**1981**	**1991**	**2001**
Average size of holding (ha)	2.69	2.30	1.84	1.57	Na
Net cropped area (M ha)	133.20	140.30	140.00	143.00	142.20[a]
Gross cropped area (M ha)	152.80	165.80	172.60	185.70	186.60[a]
Gross irrigated area as					
% of gross cropped area	18.30	23.00	28.80	33.60	38.30[a]
Fertilizer nutrient use (kg/ha)	1.90	13.10	31.80	67.40	90.00
Food grain production (M t)	82.00	108.40	129.60	176.40	203.40
Milk production (M t)	20.00	22.00	31.60	53.90	70.80[b]
Fish production (M t)	1.20	1.80	2.40	3.80	5.40[b]
Egg production (billion, number)	2.80	6.20	10.10	21.10	28.50[b]
Share in the total value of production					
Crops (%)	82.40	84.40	81.40	74.70	75.70
Livestock (%)	17.60	15.60	18.60	25.30	24.30
Share of agriculture in					
Total exports (%)	44.30	36.80	35.50	22.50	26.60[b]
Total imports (%)	36.40	37.00	18.30	11.30	11.50[b]
Crop yields (t/ha)[c]					
Rice	1.01	1.11	1.29	1.74	1.94
Wheat	0.85	1.32	1.71	2.33	2.70
Coarse cereals	0.71	0.85	1.03	0.91	1.05

a, b Figure corresponds to 1996/97 and 1997/98, respectively.

c Crop yields are three-year averages beginning with the year indicated in column headings, except last column which is average for 1999-01.

Source: RBI (2000); *Economic Survey* (various years)

important in recent years. Much of the growth in TFP has been attributed to investment in agricultural research which provided high payoffs (Evenson et al. 1999; Mruthyunjaya and Ranjitha 1998).

Overall India's agricultural achievements are impressive, with increased per capita food production and accumulating food stocks. Despites these successes, India faces a major unfinished agenda with respect to agricultural productivity growth. First, success in reducing poverty and malnutrition, most of which are located in rural areas, is a continuing challenge. India needs to not only improve the availability of food (through higher production and better distribution) but also generate income and employment opportunities for the poor in order to provide them the means to access food. Second, accelerated economic growth and rapid urbanization are driving demand for high value commodities, particularly livestock and horticultural products, that requires that future agricultural growth become much more diversified. Third, sustainable management and use of natural resources is a growing challenge with depletion of groundwater, agrochemical pollution, and land degradation by water-logging, salinity, soil erosion, and deterioration of soil fertility.

Fourth, public investment in agriculture in real terms has shown a persistent decline, while subsidies for agriculture have increased over time, despite the new economic policies. The decline in public investment has serious implications for agricultural growth and poverty reduction (Roy 2001). Fan et al. (1999) found that investment in agricultural research provides a high marginal return relative to other investments in terms of both growth and poverty reduction, and this return may now be higher in rainfed areas. Careful targeting of public investment, both in terms of sub-sectoral and regional priorities, and efficient utilization of existing infrastructure, especially irrigation, is essential for achieving growth of 4% per annum contemplated in the current national agricultural policy. However, high levels of subsidies compete with funds available for needed public investment, including investment in agricultural research.

The current national agricultural policy envisages that market forces will guide future agricultural growth through domestic market reforms, an increasing role for the private sector, and removal of price distortions. The policy of interventions in food grain markets to stabilize prices will continue, but these interventions will be made more effective and efficient (for example, by improving management of the Food Corporation of India and by targeting public distribution of food grains to the poor). These reforms, coupled with a focus on value addition and commercialization, improved product quality and strengthening comparative advantage, are essential for successful transition to a knowledge-based and competitive agricultural sector. The role of the agricultural research system will be central in these processes.

3. Historical and Institutional Development of the Indian Research System

Historical evolution

The first organized attempt to promote agricultural development, including R&E, in India began with the establishment in the last quarter of the nineteenth century of the Department of Revenue, Agriculture and Commerce in the Imperial and Provincial governments, together with a bacteriological laboratory and five veterinary colleges. These were followed around 1905 by the establishment of the Imperial (now Indian) Agricultural Research Institute (IARI) and six agricultural colleges in 1905.[2] A major milestone in the history of Indian agricultural R&E system was the establishment of the Imperial (now Indian) Council of Agricultural Research (ICAR) in 1929 as a semi- autonomous body to promote, guide and coordinate agricultural research in the country. At about the same time (1921 to 1958), a number of central commodity committees were also constituted for the development of commercial crops (cotton, lac, jute, sugarcane, coconut, tobacco, oilseeds, arecanut, spices, and cashewnut). These semi-autonomous committees, financed by government grants and revenues from a levy or cess on the output of each commodity, set up research stations for each commercial crop. Initially, the commodity committees served the interests of the imperial government (by providing revenue and ensuring raw material for industry), but later they focused on national development objectives, including research. Participation on the commodity committees was broadened to include producers and representatives of trade and industry.

An important institutional innovation in the post-independence period was the establishment of the All India Coordinated Research Projects (AICRP) initiated in 1957 under ICAR to promote multidisciplinary and multi-institutional research. The success of the first of these for maize led to

[2] One college established in Faisalabad is now in Pakistan, and the others are at Pune and Nagpur (Maharashtra), Kanpur (Uttar Pradesh), Sabor (Bihar) and Coimbatore (Tamil Nadu).

establishment of a large number of AICRPs covering all major commodities and the concept also spread to non-commodity research.

In 1965, ICAR was mandated to coordinate, direct and promote agricultural research in the country, by bringing under its control all research stations previously controlled by the commodity committees and the various government departments. Subsequently, the Department of Agricultural Research and Education (DARE) was created in the central Ministry of Agriculture to facilitate linkages of ICAR with the central and state governments and with foreign research organizations.

On the recommendation of two joint Indo-American review teams (1955 and 1960), state agricultural universities (SAUs) were established on the land-grant pattern of the US. The first SAU was opened at Pantnagar in the state of Uttar Pradesh in 1960. These SAUs were autonomous in nature and funded by the government of the respective state. The SAUs integrated education with research and to some extent, frontline extension, although mainstream extension remained in the state departments of agriculture.

A number of international agencies played important roles in the development of the public agricultural R&E system in India. Notable among these were the Rockefeller Foundation for providing support to AICRPs (Lele and Goldsmith 1989), and the US Agency for International Development which played an active role in the establishment of the SAUs and training of faculty through partnerships with US land grant universities. The World Bank has provided considerable resources to agricultural research from 1980. The initial phase of this support emphasized the development of research infrastructure and human resources while recent support has focused on strategic research areas, priority research themes, and institutional reforms.

The current structure of the public research system

Currently, the public agricultural R&E system comprises ICAR and its various institutes, and the SAUs, and their various campuses and regional institutes. At the center, ICAR funds and manages a vast research network of institutes consisting of: (i) national institutes for basic and strategic research and post-graduate education,[3] (ii) central research institutes for commodity-specific research; (iii) national bureaux for conservation and exchange of germplasm and soil survey work; and (iv) national research centers (NRCs) for conducting applied commodity-specific strategic research in 'mission mode'.[4]

In addition, ICAR manages a large number of AICRPs (the coordinate programs) which draw scientists from both ICAR institutions and the SAUs. Most AICRPs centres are located on SAU campuses under the administrative control of the respective SAU. However, for the most important AICRPs (e.g., rice, wheat, maize, cattle, oilseeds, water, cropping system, and biological control of pests), ICAR has established special project directorates comprising a team of multidisciplinary scientists with their own research infrastructure under ICAR administrative control.

In 2002, ICAR had 5 national institutes (including one academy for agricultural research management), 44 central research institutions, 5 national bureaux, 10 project directorates, 33 NRCs and 82 AICRPs (ICAR 2000/01). In addition, ICAR established 261 *Krishi Vigyan Kendras* (agricultural science centres) or KVKs at the district level that are responsible for transfer of new technologies and training of farmers. Some of these KVKs are managed by SAUs and non-governmental organizations (NGOs). In addition, there are eight training centres for 'training of trainers' in specified areas/sectors such as livestock, horticulture, fisheries, and home science.

At the state level, there are now 34 agricultural universities in the country with agricultural faculties (i.e., agriculture, veterinary, engineering, and home science). Depending on the nature of the state's agriculture, SAUs may also have faculties of horticulture, fisheries or forestry and some SAUs are exclusively for animal sciences. In addition, there is one central agricultural university under ICAR to cater to the needs of small states in north-eastern India. SAUs also have zonal research stations to address research problems for each agroclimatic zone.

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[3] Four national institutes are recognized as 'deemed university' and these also impart education in their respective field of specialization.

[4] Mission mode research is a multidisciplinary research directed to the development of technologies or components of national importance. NRCs are smaller than other institutes and organized into multidisciplinary teams.

Besides the traditional national agricultural research system (NARS)—that is, the ICAR/SAU system—there are non-agricultural universities and organizations supporting and/or conducting agricultural research directly or indirectly. For example, the Department of Biotechnology (DBT), Department of Science and Technology (DST) and Department of Scientific and Industrial Research (DSIR) all under the central Ministry of Science and Technology support and conduct agricultural research at their institutes and sometimes fund research in the ICAR/SAU system. Similarly, a number of non-agricultural universities have faculties of agriculture.

Private-sector development

Initially a few private companies dealing with agricultural inputs (e.g., pesticides, fertilizers, and machinery) invested modestly in product development, although there was little effort to establish in-house research capacity. The situation changed in the 1980s with the growing availability of trained scientists, rapid expansion of markets for agricultural inputs and processed foods, and liberalized policies to support private sector development in general. The private sector now supplies half the certified seed, half the fertilizer, and most of the pesticide and farm machinery sales. Private investment in research currently focuses on hybrid seed, biotechnology, pesticides, fertilizer, machinery, animal health, poultry, and food processing.

The government has provided strong incentives in the form of tax exemption on research expenditures and venture capital, and liberal policies on import of research equipment to encourage participation of the private sector in research. The most significant development has occurred in the seed sector after implementation of a new Seed Policy in 1988 which allowed import of seed materials, as well as majority ownership of seed companies by foreign companies (from 1991). A number of foreign seed companies entered the market, and several local seed companies have established considerable research capacity (Pray et al. 2001). Some local companies collaborate with overseas companies for access to proprietary tools and technologies. Private hybrids now account for a significant proportion of the market for sorghum, maize, and cotton (Pray et al. 2001; Singh et al. 1995) and companies with some foreign ownership account for about one-third of this market (Pray and Basant 2001). Developments in biotechnology have further strengthened these trends.

To provide additional stimulus to private research, India has recently approved a bill for The Protection of Plant Varieties and Farmers Rights Act (2000) to provide intellectual property protection to breeders. At the same time, it gives special emphasis to farmers' rights to save, exchange, and sell seed. India has also amended the Patent Act (1970) to make it compatible with WTO agreements. The Patent (Second Amendment) Act 1999 grants provisional product patents that should stimulate research in agricultural chemicals and the animal health sectors.

Finally, participation of private non-profit organizations in agricultural research has also increased overtime. There are now a few private foundations, as well as NGOs actively engaged in agricultural research. In particular, the MS Swaminathan Research Foundation and Mahyco Research Foundation have developed considerable research capacity with a national presence and are working in close collaboration with the ICAR/SAU system. In addition, there are many small regional or local NGOs engaged in agricultural research, such as those managing some ICAR- sponsored KVKs.

Contemporary developments

The ICAR/SAU system has reached a stage where it needs to consolidate past gains through modernization of research infrastructure, development of human capital, innovations in research management, and stronger linkages with clients. The system is responding to these challenges, albeit to varying degrees and speed (Mruthyunjaya and Ranjitha 1998). Several of these challenges will be addressed in the final section; here, we note two recent developments—ecoregional research initiatives for research planning, and response to new science.

Ecoregional research initiatives

Although the Green Revolution technologies were rapidly adopted in large areas, further gains in irrigated areas, as well as in rainfed areas that have enjoyed less benefits, require more location-specific research to adapt technologies to site and seasonal conditions. The organization of the Indian NARS through ICAR institutes with a national or regional mandate with a strong commodity and disciplinary orientation, and SAUs based on political boundaries, has constrained the ability to respond to this challenge. Accordingly, an ecoregional approach to planning and organizing agricultural research was introduced from 1978 in order to better target research efforts, integrate research across disciplines, and locate appropriate sites for research programs. Under the National Agricultural Research Project (NARP) implemented with World Bank funding, the entire country was divided into 126 agro-climatic zones consisting of several districts. In each of the zones, a research station was established under the specific SAU to carry out applied and adaptive research relevant to the zone (Ghosh 1991). An advisory committee with wide representation of farmers, NGOs, and the state department of agriculture, was created to link scientists more closely with farmers and other stakeholders, and research programs were developed through a 'bottom up' participatory approach. These zonal research stations also actively provided technical support to the KVKs and state extension departments.[5]

The ecoregional approach was further developed under the National Agricultural Technology Project, again implemented with financial support from the World Bank. Under NATP, the country is divided into five ecoregions (arid, coastal, hill and mountain, irrigated and rainfed), which are further delineated into fourteen production systems. Research programs for each of the production systems are identified in a participatory mode and implemented using a multi-institutional and multidisciplinary systems approach. These research programs are intended to complement the AICRPs and the zonal research stations, by promoting a systems approach to planning and implementing research.

Biotechnology

Over the past decade or so, revolutionary advances in biotechnology are transforming the way agricultural research is organized and funded. To meet this challenge, the Department of Biotechnology (DBT) was created

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[5] Under NATP 58 zonal research stations are being re-mandated to take additional function of KVK.

in 1986 in the Ministry of Science and Technology to support research, and human resources and infrastructure development in biotechnology related to agriculture, health care, environment and industry. DBT has established six autonomous institutions for conducting biotechnology research (Qaim 2001). It also funds biotechnology research in other institutions including ICAR institutes and SAUs, through special projects and grants, and through its competitive grants program. In addition, ICAR has developed capacity in biotechnology research in several of its research institutes, as well as created new entities exclusively for biotechnology research. These initiatives have allowed India to develop considerable capacity in this frontier area of science, although much of it is outside the ICAR/SAU system.[6] At least 10 research institutes have capacity in genetic engineering.

The private sector is also responding to developments in biotechnology with up to 45 companies active in agricultural biotechnology research broadly defined, for a market that was estimated to be worth US$75 million (Rs 2,663 million) in 1997 (Qaim 2001). The companies include both foreign and domestic companies although all of the latter with a significant biotechnology program have developed joint ventures with global companies. At least three foreign companies have major biotechnology research facilities in India, one with a team of 34 scientists (Pray and Basant 2001).

Given that several products are now moving into field testing and commercial release, the government is currently focusing on establishing a framework to regulate biotechnology research and the testing and release of genetically modified organisms (GMOs). The Review Committee on Genetic Manipulation (RCGM) of DBT (comprising members from various scientific organizations) is responsible for monitoring of biotechnology research, safety-related aspects, and import and export of GMOs. The Genetic Engineering Approval Committee of the Ministry of Environment and Forest assesses GMOs for environmental safety and approves them for wider scale testing and commercial release. India has allowed field experiments of GMOs, and approved commercial cultivation of transgenic cotton in 2002.

[6] Only 8 (6 ICAR and 2 SAUs) of the 18 public institutes identified by Qaim (2001) with significant capacity in biotechnology are part of the traditional NARS.

4. Funding of Research

The amount of research funding and the mechanisms for fund allocation are powerful instruments of research policy in India as elsewhere. Most funds for agricultural research in India are allocated through block grants, but funding through competitive grants is now gaining acceptance, especially for operating and equipment costs.

Methods for allocating public funding

Most public funding to agricultural R&E in India is in the form of block grants to ICAR and the SAUs determined according to Five Year Plans. At the beginning of each Plan, the Planning Commission constitutes a working group to agree on broad agricultural R&E priorities and to assess financial requirements for their implementation. Recommendations of the working group are discussed in several consultations between DARE and the Planning Commission. Based on the outcome of these deliberations DARE develops its Five Year Plan, and plan outlays are communicated by the Planning Commission on approval of the Ministry of Finance. This is followed by development of Five Year Plans for each ICAR institute. Depending upon the level of proposed outlays, these plans are evaluated by committees composed of directors of the institutes, senior research managers from ICAR, and representatives of the Planning Commission, Ministry of Finance and other departments. The approved outlays are the basis for funding of each institute during the Plan period, and funds received are labeled ‘Plan funds’. The on-going activities of the previous Plan are financed under ‘non-Plan funding’, which primarily pays salaries and other fixed costs.

A similar procedure is followed for state funding, except that state allocations are first done by the Planning Commission as part of total Plan allocations to a state. Expenditures on R&E (plan and non-plan) are then approved by the respective state governments.

This process implies that resource allocation decisions are made through informed opinion and collective wisdom regarding research priorities that address developmental objectives. There is direct involvement of institutions in the allocation decisions, and input from other stakeholders is obtained through wide consultations. Historical trends also play an important role especially for non-Plan funding.

Use of formal economic methods for allocating agricultural research funds is a recent phenomenon in India. These methods are being tested under NATP for research programs at the ecoregional level. Another innovative method for resource allocation is followed in the AICRPs where ICAR and SAU agree to fund in the ratio of 75% and 25%, respectively. The locations of AICRP centres are decided based on priority ecoregions and funds are allocated accordingly.

In general, resource allocation appears to have been congruent with the distribution of production across regions**.** Jain and Byerlee (1999) computed a congruency index of 0.88 between value of production and resource allocation in 20 production environments for wheat. The main discrepancy has been the strong tendency for research intensity to be higher in smaller production environments. Over time too, there is good evidence that resources have shifted in accordance with changing production conditions. In the case of wheat, this implies an increase in resources allocated for breeding for late planting, and a decrease in resources for rainfed areas, in accordance with increased cropping intensity and irrigation, respectively.

Competitive funding

Competitive funding is gaining popularity in India. It is regarded as a powerful mechanism to direct funds to high priority areas, improve quality and accountability, and promote wider participation of research providers and innovative partnerships. There are at least five different competitive funds operating at the national and state levels to support agriculture research. Unlike other developing countries where these funds have mostly been established with donor support, several of the Indian funds were initiated with domestic resources and may therefore be more sustainable (Carney et al. 2000). Although these funds are increasing, they still account for a small proportion of the total public research funding (about 3%).

The Ad hoc Research Scheme of ICAR, financed by the agricultural cess on selected commercial crops, is the oldest competitive fund, supporting research in emerging areas and research to fill critical technology gaps. The Competitive Grant Program (CGP) of NATP and Competitive Agricultural Research Program (CARP) of Uttar Pradesh Council of Agricultural Research (UPCAR) are of recent origin and donor supported.[7] The competitive funds of DST and DBT support upstream research in all fields of science, including agriculture. All these funds have similar operational modalities—short-term research projects selected through peer review, and provision of funds for operating costs but not for salaries and infrastructure (Table 2).

Although these funds are operating quite successfully and are in high demand, a number of issues need to be addressed. The proposals are not invited against well-defined research priorities and therefore the number of proposals is large and the success rate is low (CGP addresses this problem to some extent). Most operate at the national level, and there is no systematic mechanism to ensure that regional priorities are addressed. This problem, coupled with weak capacity to develop competitive proposals in institutions located in less developed regions leads to a low success rate in those regions. More effort is needed to train scientists in weaker institutions in developing research proposals. The experience of CGP has also shown that a prompt evaluation of proposals is important in attracting quality proposals. Finally, research projects under competitive grants are time-bound and therefore it is critical to have timely release of funds and efficient administrative procedures.

Overview of sources of funding and fund flows

Figure1 provides a schematic representation of the sources and flows of funds in the Indian NARS around 2000. In spite of the fact that agriculture is a state subject, ICAR funded by an annual block grant of Rs 13 billion (US$ 300.9 million) in 2000 from the central government, has the major

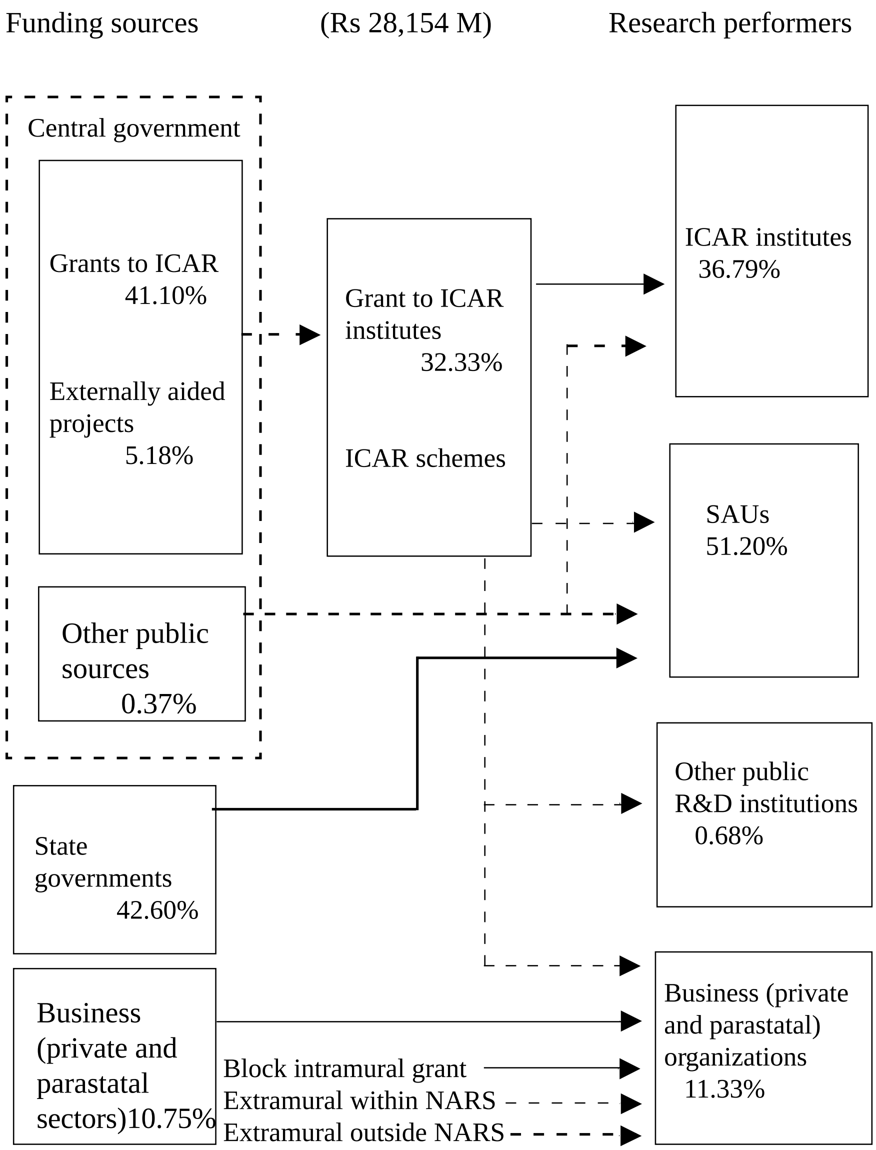
[7] The CGP has developed a systematic and rigorous procedure for evaluation of proposals based on objective criteria such as relevance of research, competence of researcher, scientific quality, chances of research success, and equity concerns such as development of marginal areas, poverty alleviation, and gender impact.

Table 2. Important competitive funds for agricultural research in India

	AP Cess Fund *Ad-hoc* Research Scheme of ICAR	Competitive Grant Program of NATP, ICAR	DST	DBT	CARP scheme of UPCAR
Institutional base	ICAR Headquarters	ICAR Headquarters (Implementation Unit of NATP)	DST Headquarters	DBT Headquarters	UPCAR
Size of the fund	Rs 251 M (1999/2000)	Rs 914 M for five years (1998/99-2002/03)	Rs 455 M (1998, annual)	Rs 515 M (2000, annual)	Rs 108 M for five years (1998/99- 2002/03)
Source of finance	Collection of cess by GOI under the Agricultural Cess Act of 1940 and 1966 (Amendment)	NATP funds of the World Bank	DST budget	DBT budget	World Bank funds
Purpose	To fill critical gaps in scientific fields, and to address research problems for agriculture and allied sectors through short term results-oriented *ad-hoc* research	To support main thrusts of agro-ecosystem research under NATP with enhanced basic and strategic research, product, process and market development with greater partnership between public and private sectors	To promote research in front-line areas of science and engineering, develop research capability and encourage young scientists	To support R&D program in biotechnology for achieving excellence, development of new products/ processes, patents and technology for application	To draw on comparative advantage of research capacity outside the SAUs including private sector for synergies and cost effectiveness through collaboration, teamwork
Who are eligible to apply for financing	All public, recognized private and non-governmental organizations capable of undertaking research	All public, private (foundations/ companies) and non-governmental research organizations; international research centres in collaboration with the national programs on cost sharing basis	Recognized public, private and non-governmental organisations capable of undertaking research	Recognized public, private and non-governmental organisations capable of undertaking research	Recognized public, private and non-governmental organisations capable of undertaking research and located in the state of UP
Components of project grant	Operating expenses, equipment costs, salary of contract staff; minor civil works in exceptional cases	Operating expenses, equipment costs, salary of contract staff; minor civil works in exceptional cases	Operating expenses, equipment costs, salary of contract staff	Operating expenses, equipment costs, salary of contract staff	Mostly operating expenses; equipment costs, training and consultancy only for basic and strategic research

Source : Pal (1999)

Figure 1. Funding channels for Indian agricultural R&E, 2000



Note: State funding data are budget/revised estimates. Apportioning ICAR funding was also done using budget estimates. Private R&D investment data were available for 1997 (DBT 1999) which were extrapolated for 2000 using the growth rate reported in Table 5. In this figure, extrapolated expenditure on seed research reported in Table 5 was also added, as DST data do not cover private seed research.

Source: Compiled by the authors from various sources.

responsibility for agricultural research. ICAR also manages funds received as grants and loans from multilateral donors and collaborative research programs funded by bilateral donors and international organizations. The World Bank is the dominant source of such funds. Currently, ICAR manages a loan under NATP of US$180 million (about Rs 8 billion at the exchange of Rs 43.3 per US$ in 2000) from the World Bank for strengthening research and extension for the period 1998-2003. A small loan (less than US$ 10 million for 1995-2001) was also provided for human resources development in SAUs in four states, which may be scaled up and extended to other states in a later phase.

In addition, ICAR manages the AP Cess Fund levied at 0.5% (ad valorem) on specified export commodities and accounting for about 2% of the total ICAR budget in 2000.[8]

Finally, with implementation of a new policy on self generation of income (ICAR 1997), ICAR earns some resources through consultancies, contract research and services, sale of seed and other planting material, and royalties on research products through partnerships with the private sector. However, progress has been modest—ICAR could generate only about 3% of its total budget in 2000 through these means.

Overall, the central government provides 52% of public funding for agricultural R&E in India, which almost entirely passes through ICAR.[9] A significant proportion of the ICAR funds (30%) are made available for extramural funding (Figure 1) and a large proportion of these funds (87%) is directed to the SAUs. Non-agricultural public research institutions and private research organizations (for profit and non-profit) obtain 7% and 6%, respectively, of ICAR's extramural funding through competitive research program and support to KVKs.

In terms of funding mechanism, it is estimated that about 30% of the extramural funding from ICAR is made through the AICRPs in the form of

[8] India use a financial year from April to March. For simplicity, only the year of completion of the year is reported—that is 2000 refers to 1999/2000.

[9] The other central government funding is through the Ministry of Science and Technology (DBT and DST).

block grants, 12% through competitive funding, 34% through donor-funded projects, 17% through grant to KVKs, and 7% as development grants to SAUs.[10]

Annual block grants from the state governments to the SAUs totaling Rs 12 billion in 2000 are the second major source of funding. Practically all of these funds are used intramurally by the SAUs. Use of state funds by ICAR institutes does not exist. Only a small competitive fund in Uttar Pradesh is open to all research organizations located in Uttar Pradesh, including ICAR institutes.

The remaining significant source of research funds is private firms which is nearly all used for intramural research and accounts for about 11% of the total. Private funding of research in public organizations is negligible. The most cited example was a research contract between ICAR and Mahyco Research Foundation for hybrid rice development in 1995. Such linkages should increase in future because of concerted efforts being made by ICAR, but it is unlikely that these partnerships will make a significant contribution to total agricultural research efforts in the country for many years.

In terms of spending (the right side of Figure 1), all ICAR institutes together accounted for 37% of the national expenditure on agricultural R&E, SAUs for 51% and the remaining 12% was spent by other public and private organizations.

Trends in overall public funding for research

India has consistently committed substantial government funds for research in all fields of science including agriculture. Figure 2 shows the trends in public funding, in real terms, to agricultural R&E in India. Total funding for agricultural R&E increased in real terms (1999 prices) from Rs 2.46 billion ($284 million 1999 P PP or international dollars) in 1961 to Rs 7.57 billion ($875 million) in 1981. This rose to Rs 25.0 billion ($2,893 million)

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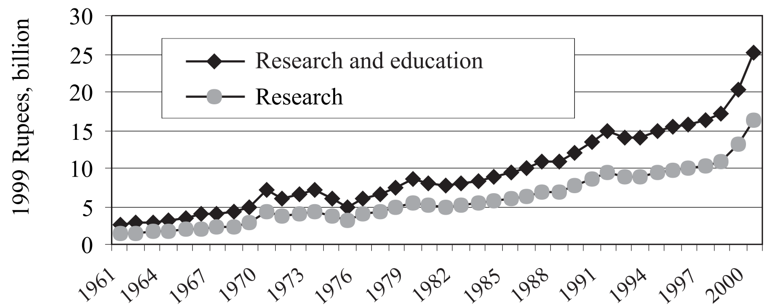
[10] Estimates of transfer of funds through competitive grants, KVK and externally aided projects are available in ICAR budget records. AICRPs funds were apportioned based on percentage of centres located on SAUs (70%) and ICAR institutes 30% (*ICAR Vision 2020*).

Figue 2. Government expenditure on agricultural research and education



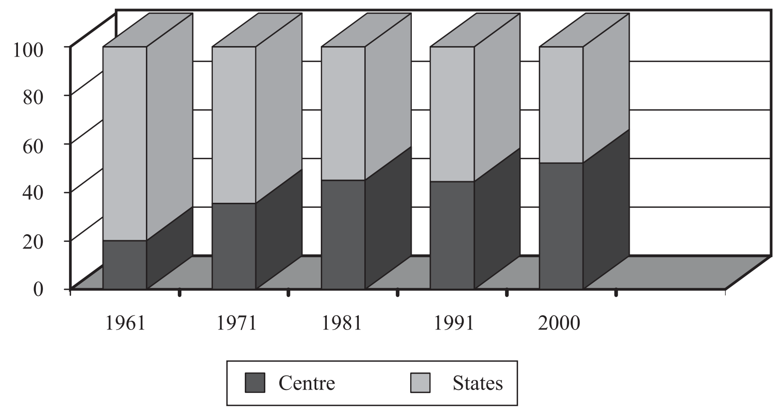
in 2000—a ten-fold increase over the past four decades (Figure 2).[11] An increasing trend is observed for both central and state funding. Funding from the states grew rapidly during the 1960s because a large number of SAUs were established during this period. Central funding has outpaced state funding thereafter and their shares became almost equal in the 1980s and the 1990s (Figure 3).

Using simplistic assumptions[12], nearly three-fourths of these total R&E expenditure is spent on 'research' (net of education), and in absolute terms 'research' expenditure reached Rs 16.2 billion at 1999 prices ($1,898 million 1999 international dollars) in 2000 (Figure 2). Overall public research funding grew at 3.16% in the 1970s, 7.03% in the 1980s, and slowed to

[11] Pal and Singh (1997) have compiled the research funding series in India for the period 1961 to 1995 from various government publications. These data series were used with minor refinement and updated for the subsequent years from the same sources (Comptroller and Auditor General of India (various years), Ministry of Finance (various years) and the Reserve Bank of India (various years) and Reserve Bank of India (2000)). The nominal expenditure data were first converted into constant 1999 local currency (Rupees) using the implicit GDP deflator. These data were then converted into 1999 international dollars using the purchasing power parity (PPP) conversion factor (8.65) suggested by the World Bank.

[12] Separation of research expenditure from total research and educational expenditure is rather difficult, particularly for SAUs. Using survey estimates for one year for SAUs (Rao and Muralidhar 1994) and information available in budget documents of ICAR, the share of 'research' expenditure (net of education and frontline extension) was computed as 80% for ICAR and 50% for SAUs (see Table 6.7). In the absence of time series data on these shares, constant shares were used to estimate a time series on 'research' expenditures.

Figure 3. Percentage share of the centre and states in the government research expenditure



4.61 in the 1990s. These trends show strong political commitment to research in spite of a pluralistic political system, changes in governments, and shift in public investment priorities.

Intensity of research funding

Another way to assess funding is to compute various intensity ratios such as expenditure per agricultural worker, per unit of agricultural land, and percentage of agricultural GDP (AgGDP) (Table 3). All the intensity ratios registered impressive growth over time in spite of significant growth in population, land area, and AgGDP. Agricultural research expenditure as a percent of AgGDP increased significantly during the 1960s and 1980s, but remained around 0.3 % during the 1990s.[13] This slowdown is worrying given that the average for all developing countries is 0.6 percent and 1.0 percent globally (Pardey and Beintema 2001). Part of the difference can be attributed to the relative importance of agriculture and economies of scale and scope in agricultural research (Alston et al. 1998), but there appears to be a clear case of under-investment as China, a country of comparable size and stage of development, spends 0.43% of AgGDP on research. Even comparing agricultural research with general science and technology

[13] Our estimates are considerably lower than IFPRI estimates for earlier periods. See www.asti.cgiar.org (visited on 20.12.01)

Table 3. Intensity of public agricultural R&E funding: All India

Indicator	1961-63	1971-73	1981-83	1991-93	1997-99
R&E expenditure					
Constant local currency units (M 1999 rupees)	2,697	6,576	7,892	14,335	17,885
Total expenditure (M 1999 PPP dollars)	312	760	912	1,657	2,068
Per capita expenditure (1999 PPP dollars)	0.71	1.39	1.34	1.97	2.14
Expenditure per agricultural worker (1999 PPP dollars)	2.38	6.04	6.17	8.94	9.76
Expenditure per hectare of net cropped area (1999 PPP dollars)	2.29	5.47	6.50	11.75	14.52
Expenditure as % of AgGDP	0.20	0.35	0.36	0.44	0.42
Research expenditure (net of education and extension)					
Constant local currency units (M 1999 rupees)	1,511	4,054	5,057	9,069	11,404
Research expenditure (M 1999 PPP dollars)	175	469	589	1,049	1,318
Research expenditure as % of AgGDP	0.11	0.22	0.23	0.28	0.31

Note: Figures are three-year averages; 1961 refers to 1960/61 and so on.

Source: Developed by the authors using data available in the sources mentioned in Footnote 11, and GoI.

research in India, ICAR received only about 10% of the total research funds of the central government in 1997 (although state funding is more important for agriculture than for other fields).

Funding by states

Table 4 gives real growth and intensity of agricultural research funding at the state level. The growth in real funding was highly uneven among states during the 1970s. These differences narrowed in the 1980s with steady growth in all states. The growth of total state funding increased from 1.3% per annum in the 1970s to 8.2% in the 1980s, but slowed to 3.8% in the

1990s. The intensity of state funding has increased in all states since 1980s, except in West Bengal. However, there remains wide variation in the intensity between states with comparatively high ratios (over 0.4% of AgGDP) in Himachal Pradesh, Tamil Nadu, Haryana, Maharashtra, Gujarat and Kerala, and very low ratios (less than 0.2%) in the states of Madhya Pradesh, Rajasthan, Uttar Pradesh and West Bengal.

A host of factors may explain variations in the intensity of agricultural research. (Alston et al. 1998; Rose-Ackerman and Evenson 1985; Judd et al. 1986). Pal and Singh (1997) applied a political economy model to analyze the determinants of the level of state funding to agricultural research in India using cross-sectional and time-series data for the period 1982 to 1994. Although the results were mixed and unmeasured state-specific attributes were important, per capita state funding was found to be strongly related to per capita AgGDP indicating that states with higher income level spend comparatively more on agricultural research. Rural literacy and the share of agriculture in government expenditure also had a positive and significant effect on research intensity. Other factors such as sources of growth in agriculture (e.g., expansion of agricultural land and irrigated area), crop diversification, and terms of trade were non-significant. That is availability of public resources and the importance assigned to agriculture play key roles in decisions on research resource allocation[14] .

Donor funding

USAID has been a significant funder of agricultural research. Beginning from the early 1960s, USAID supported building of the SAUs up to 1977. This was followed by other projects including a major agricultural research project in the 1980s (Alex 1997) when USAID support was at its peak. In total USAID invested some US$108 million ($1999)or Rs 4.5 billion (at the exchange rate in 1999) in agricultural research in India to about 1990, when support was terminated.

Beginning in 1980, the World Bank became a significant supporter of agricultural research, first at the state and zonal levels, and from 1997 at

[14] Similar conclusion was also drawn in another study analyzing determinants and impact of public investment in Indian agriculture (Roy 2001).

Table 4. Growth and intensity of agricultural R&E funding by state governments

	Annual growth rate in real funding			Funding per ha		Funding per agricultural worker		Funding as share of AgGDP		Share in the total funding by all states
	1972-81	1982-91	1992-99	1981-83	1995-97 [a]	1981-83 [b]	1991-93 [b]	1981-83	1997-99	1997-99
	(%)			(1999 Rupees)				%		(%)
Andhra Pradesh	11.40	6.47	5.23	26.21	78.02	18.25	30.10	0.16	0.28	8.08
Assam	-0.07	9.51	-0.03	63.66	95.67	na	87.62	0.28	0.33	2.84
Bihar	18.52	8.55	5.10	25.95	71.97	12.28	16.09	0.13	0.25	4.96
Gujarat	0.61	9.71	4.78	28.03	85.20	40.83	72.05	0.19	0.41	7.52
Haryana	28.56	5.16	8.18	70.58	196.27	113.92	144.11	0.28	0.44	6.23
Himachal Pradesh	-0.09	12.76	10.21	150.68	567.78	na	159.68	0.62	1.52	3.31
Jammu & Kashmir	-0.08	10.97	12.79	73.35	295.13	48.96	na	Na	Na	2.25
Karnataka	12.91	7.54	3.03	22.57	52.07	26.29	38.75	0.19	0.28	5.74
Kerala	25.40	5.23	1.85	100.08	242.89	77.59	148.17	0.31	0.41	5.65
Madhya Pradesh	-0.08	13.29	1.09	5.19	18.16	6.40	18.68	0.07	0.14	3.42
Maharashtra	0.74	7.06	2.43	42.04	84.94	50.95	67.03	0.39	0.43	14.21
Orissa	7.75	6.50	-0.02	14.27	27.85	13.41	26.12	0.10	0.21	1.78
Punjab	3.43	10.28	2.41	72.66	155.01	106.65	166.77	0.24	0.30	6.48
Rajasthan	3.63	10.95	3.58	9.60	27.85	20.24	35.55	0.12	0.18	4.13
Tamil Nadu	3.80	13.00	7.44	36.15	160.20	17.90	45.33	0.21	0.59	9.34
Uttar Pradesh	-0.06	5.74	2.06	28.63	45.07	20.50	25.95	0.13	0.16	8.03
West Bengal	12.13	2.35	4.73	46.19	65.48	30.10	26.55	0.17	0.17	4.89
Average for all states	1.34	8.23	3.82	29.84	67.99	28.28	43.16	0.19	0.24	100[c]

Note: Figures for the R&E intensity are three-year averages; 1972 refers to 1971/72 and so on.

[a] Triennium average of NCA ending 1997. [b] Census data for agricultural workers for the year 1981 and 1991, respectively.

[c] Column total may not add up to 100 percent as expenditure for small states is not reported here.

Source: As in Table 3

the national level. The World Bank has also supported human resources development in the SAUs from 1995 and a number of state projects have financed agricultural research, especially in Rajasthan and Uttar Pradesh. In total, the World Bank has provided US$538 million ($1999) or Rs 22.6 billion (at the exchange rate in 1999) to agricultural research since 1975 (Appendix A2).[15]

One important implication of these results is that in low-income countries, such as India, donor support to agricultural research can help increase intensity levels. However, long-run funding sustainability requires India give high priority to agricultural research investment over non-developmental expenditures many of which are subsidies. This is particularly so when the rates of returns to agricultural research are found to be very attractive.

Private research funding

The recent rapid growth in private research spending in India has outpaced the capacity to track its intensity, orientation, and impact. Based on broad estimates for each subsector (seed, pesticide, machinery, livestock, and food processing) total private or business funding for agricultural research (including funding by state-owned enterprises) in India doubled from Rs 800 million (US$ 24 million) in 1985 to Rs 1,695 million (US$ 51 million) in 1995 (Table 5). In terms of 1999 international dollars, the funding increased from $119 million to $253 million in this period. Private research funding has grown at 7.5% compared to 5.1% in the public sector over the same period, and accounted for 11% of total funding of agricultural research in 2000 (Figure 1).

Table 5 shows that the largest investment occurs in pesticides and food processing, followed by seed, fertilizer, and machinery. The most rapid increases in private growth have occurred in food processing, seeds, veterinary products, and sugar. More recently, there has also been strong investment in biotechnology, animal health and the poultry sector. This has

[15] These are conservative figures for the World Bank and USAID assistance, since we have assumed that most donor aid is spent in foreign currency and have also deflated with the US GDP deflator, besides converting into international dollars.

Table 5. Agricultural research expenditures by private firms and state-owned enterprises, 1984-95

Industry	Research expenditure, M 1995 Rupees		Research expenditure, M 1999 PPP $ *		Annual rate of growth (%)*	% in state enter-prises
	1985	**1995**	**1985**	**1995**	**1985-95**	**1995**
Seed	44.42	164.66	6.62	24.55	13.1	0
Machinery	123.58	216.43	18.43	32.27	5.61	13
Fertilizers	227.12	222.11	33.87	33.12	-0.22	67
Pesticides	300.6	568.47	44.82	84.76	6.37	15
Veterinary	30.06	90.85	4.48	13.54	11.06	5
Sugar	30.06	83.16	4.48	12.40	10.17	1
Food processing	44.75	349.70	6.67	52.14	20.56	1
Total	800.60	1,695.38	119.38	252.78	7.50	16

Source: Pray and Basant (2001)

* Computed by the authors

been accompanied by significant growth in research expenditure by multinational companies.

Agricultural research funding in India from an international perspective

Although India has one of the largest research systems in the world, the public sector still under-invests relative to other developing countries (Table 6). In the late 1990s, India invested 0.31% of agricultural GDP in research, close to China at 0.43%, but significantly lower than the average for all developing countries of 0.62% (Pardey and Beintema, 2001). Industrialized countries spent a much higher figure—2.64% of agricultural GDP—on agricultural research, reflecting their relatively higher tax base, smaller agricultural sector in relation to the economy, and often politically powerful farm lobby groups.

However, India appears to be catching up with the rest of the world in terms of growth of overall spending on agricultural research. Over the period, 1986-95, the growth rate of spending at 5% was higher than for all developing countries, and comparable with the rest of Asia which had a relatively high growth rate. One notable feature of spending for agricultural research in India is that growth has accelerated through the 1990s, in contrast with a worldwide slowdown and even decline in some countries. If India can continue this trend, research intensity should reach the average for all developing countries in the next few years.

Table 6. Public research expenditures in India relative to other regions

	Intensity (% AgGDP)	Growth rate (%/year)	
	1995	1976-85	1986-95
India	0.29	3.92	5.00
China	0.43	8.0	3.1
Latin America	0.98	4.9	2.1
Africa	0.85	2.0	0.7
USA	2.45	2.3	2.2
UK	2.63	3.8	-2.2
France	2.0	3.2	2.0
Australia	3.90	NA	1.0
All developing countries	0.62	5.4	4.1
All industrialized countries	2.64	2.3	1.6

Notes: 1. Research intensity for USA and France are for the year 1993 and 1994, respectively

2. Growth rates for USA are for the periods 1971-1981 and 1981-1993. For Australia growth rate corresponds to 1989-1995.

Source: Pardey and Beintema (2001), Pardey et al. (1999) and www.asti.cgiar.org India data are estimates by the authors.

Agricultural research does seem to be more centralized in India relative to other large countries. For example, although the federal government in the USA and the central government in India both fund around half of all agricultural research in the public sector (53 and 51% respectively), a relatively larger share of research is performed by the states in the USA compared to India (67 and 58% respectively). This is because, 39% of federal funding in the USA is transferred to the states through various mechanisms, relative to only 27% in India. However, relative to other large developing countries, India may not be unduly centralized. For example, in Brazil, the federal government through EMBRAPA, the central agricultural research corporation, accounts for about 75% of public research spending, and transfers to the states are less than 5% of this (Beintema et al. 2002).

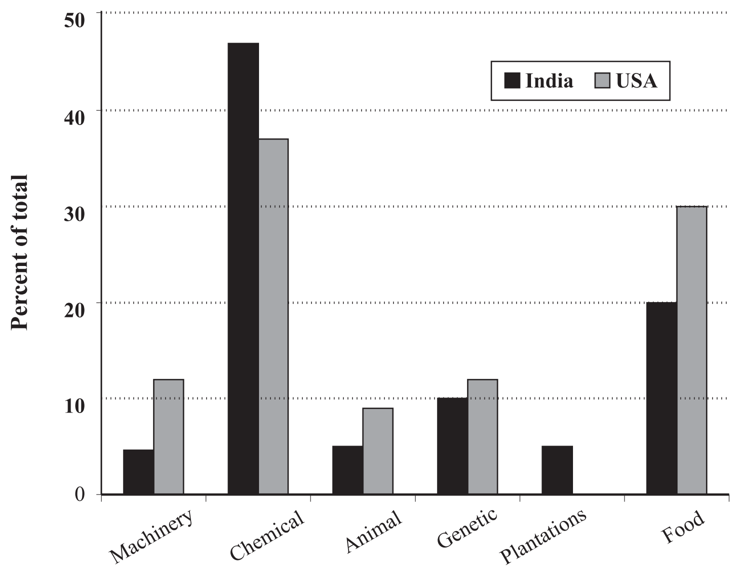
The private sector share of agricultural R&D spending in India is similar to the average for Asia (Table 7) but significantly above the average for the developing world of 5%. Within Asia, private spending has increased more rapidly in India than the average for Asia, but its share is still lower than for Malaysia and the Philippines. The composition of private spending is quite similar to that in the USA in about 1990, with spending by chemical companies and food processors as the largest share (Figure 4). However, the share of spending on genetics, including biotechnology, has increased sharply in the USA at the expense of spending on chemicals, and a similar trend is underway in India. It is also important to note that the share of research in public research organizations financed by the private sector in

Table 7. Growth of private research in Asia (Millions of 1995 U.S. $s)

	1985	1995	Annual growth rates	Private as % of total 1995
India	26	56	7.7	13.9
China	0	16		3.2
Indonesia	3	6	6.9	6.9
Malaysia	14	17	1.9	21.0
Philippines	6	11	6.1	22.4
Thailand	11	17	4.4	11.8
Pakistan	2	6	11.0	Na
Total	62	128	7.2	10.1

Source: Pray (2002)

Figure 4. Composition of private R&D investment in USA and India



Source: Pray and Basant (2001), Fuglie et al. (1997)

India is low, relative to the USA where the private sector accounts for 13% of funding in USDA, and the state agricultural universities.

5. Providers of Research: Human Resources and Patterns of Expenditures

Human resources for R&E

Although precise and consistent estimates of scientific staff in the ICAR/SAU system over time are not available, the number of scientists working in the ICAR/SAU system during the late 1980s was estimated at 4,189 scientists in ICAR and 14,851 scientists in the SAUs, giving a scientific strength of 19,040 (ICAR unpublished data sources). The number of scientists remained steady in ICAR during the 1990s (4,092 in 1998), but decreased significantly in the SAUs (17,678 in 1992) and has likely further depleted in the 1990s, because of non-replacement of retiring faculty and restrictions on recruitment.

Adjusting the number of scientists by share of research expenditure relative to extension and education (for ICAR) and percent time spent on research (for SAUs), the number of full-time scientists in the late 1990s was 2,999 in ICAR and 8,132 in SAUs, giving a total of 11,131 full-time researchers in the country—a figure similar to that in the USA (Table 8). This is a substantial increase from an estimated 5,666 full-time researchers in ICAR/SAU system in 1975, and 8,389 in 1985 (Pardey and Roseboom 1989).

The educational qualification of Indian researchers is also impressive—more than two-thirds of researchers hold a Ph. D. degree and the rest are MS holders. The proportion of women researchers is, however, very low—7.5% in ICAR and 2.1% in the SAUs.

Scientific staff are supported by a large number of technical and administrative staff. The ratio of scientists to administrative staff is especially high in the universities at 1:2.5. ICAR and to some extent the SAUs are now attempting to balance these numbers, by downsizing administrative staff.

Resource expenditure patterns

In terms of research expenditures, 37% was spent by ICAR institutes, 51% by SAUs and the rest 12% by private and non-NARS public organizations. This compares with about half of the funding provided through ICAR since there is a net flow of funds from ICAR to SAUs, largely through the AICRPs. A more disaggregated analysis of expenditures patterns by providers of R&E is difficult, as India has no ready means to track the allocation of overall expenditures below the institute level. However, a number of proxies are used in this section to gain insights into the overall allocation of expenditures.

Strategic versus applied research

One way to look at R&E funding is its allocation by types of R&E—strategic, applied, and adaptive research, extension, and education—by reviewing the mandates of research providers.[16] Basic and strategic research mainly conducted in ICAR institutes accounted for 21% of total agricultural R&E expenditure, and applied and adaptive research (some ICAR institutes, SAUs, AICRPs) accounted for 53% of the expenditure. Of the remaining, 20% was used for education and human resources development (mostly at SAUs), and 6% was allocated to frontline extension-related research—assessment, transfer and refinement of new technologies—in ICAR institutes and SAUs (including KVKs). These shares appear to be reasonably distributed although there is concern about weakening of basic and strategic research in the system. Weakening of research capacity in the SAUs because of non-replacement of retiring faculty due to inadequate funding from the state governments, is also a matter of concern. It may be noted that the US spends about equal proportion of the resources on the basic and applied research and very little on the developmental or adaptive research (Alston et al. 1999). A higher allocation for the basic research in the US is justified in view of the higher private research investment mostly directed to the development research.

[1] For institutions with mandate of multiple R&E categories such as the SAUs and the national institutes of ICAR, total expenditure was first apportioned using the respective shares of R&E categories (see footnote 12). Research expenditure was then apportioned into basic, applied and adaptive research based on the mandate of the institution.

Table 8. Scientific manpower and allocation of R&E expenditure in ICAR/SAU system

	ICAR (1996-98)[a]	SAUs (1992)[b]
Total number		
Researchers	4,092	17,678
Full-time researchers	2,999	8,132
Qualification (% distribution)		
Researchers with Ph.D. degree	68.8	62.6
Researchers with M.Sc. degree	31.2	35.7
Women researchers (%)	7.5	2.1
Ratio of scientific to technical and administrative staff	1:1	1:2.5
Allocation of expenditure[c] (%)		
Research	73.3	45.0
Education	5.2	33.0
Extension	6.1	5.0
Others (administration, publication, recruitment, etc.)	15.4	17.0

Note: Full-time researchers are arrived based on proportion of the total expenditure spent on research for ICAR, and percentage of time devoted to research for SAUs.

[a] Compiled from ICAR records

[b] Source: Rao and Muralidhar (1994)

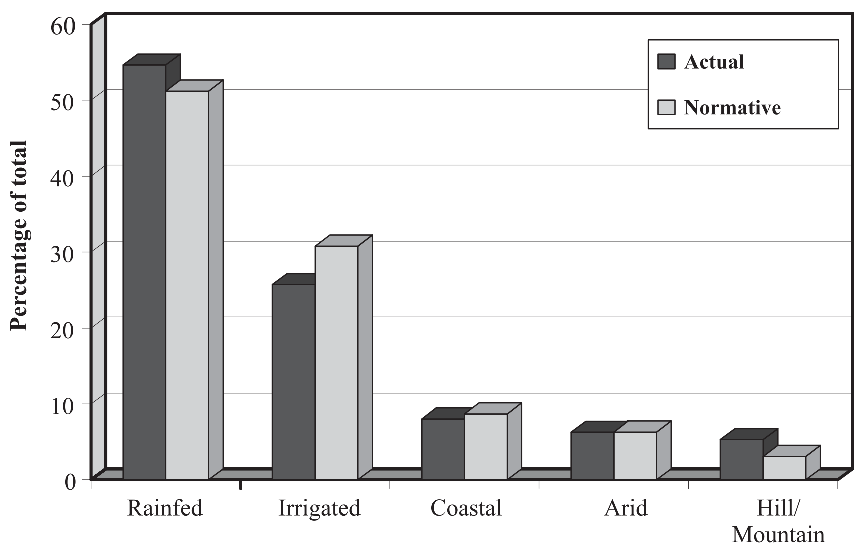
[c] ICAR expenditure also includes externally aided projects

Favored versus less-favored regions

The irrigated ecoregion received high priority during the Green Revolution period primarily because of its high growth potential. This paid rich dividends in terms of a quantum jump in crop yields, but in the process, rainfed and marginal regions were neglected. This was corrected in the Seventh Plan (1985-90), which gave high priority to research for rainfed agriculture.

To see if past imbalances have been corrected, we compared actual research expenditure in different ecoregions with the normative allocation using the congruence rule (value of production), modified by criteria for sustainability (area under degraded lands) and equity (number of female illiterates).[17] The estimates shown in Figure 5 are quite revealing—there is no indication of under investment in less-favored ecoregions. In fact, contrary to general belief, less-favored environments received slightly more resources than those justified by the efficiency criterion, even after inclusion of natural resources and equity concerns which favored allocation to rainfed areas. These very broad observations are supported by analysis of resource allocation for a specific commodity, wheat, by Byerlee and Morris (1993) who used the number of field experiments as a proxy for investment by agroclimatic zone. They found that in spite of the predominance of irrigated wheat and its high research payoffs, there was no evidence of under-investment in marginal environments. This was further reinforced by a detailed study by Traxler and Byerlee (2001) which showed that rainfed and hill environments accounted for 30% of resource allocation to wheat breeding research although these environments only produced 12% of total Indian wheat production. More revealing is the estimate that these research

Figure 5. Allocation of research expenditures by environments



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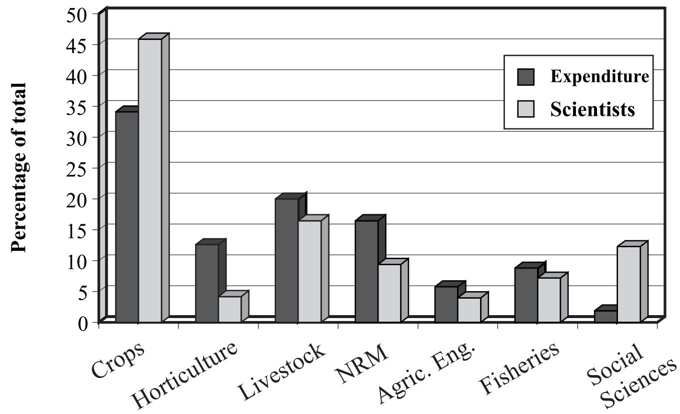
[17] These estimates are taken from a research prioritization exercise undertaken by the senior author for NATP. Since ecoregions do not correspond with state boundaries, total state research expenditure was apportioned into different ecoregions within the state based on their share in crop area for crop research, net sown area for non-commodity research, livestock population for animal science research, and state-level production for fisheries research.

Figure 6. Subsectoral allocation of research resources in ICAR, 1996-98



programs for rainfed and marginal areas only produced 1.3% of the benefits generated from wheat research in India during the post-Green Revolution period, 1976-93.

Allocation by sub-sectors and commodities

Data on research expenditure by sub-sector and commodity are only available for ICAR, including research expenditure on AICRPs in SAUs.[18] Together these represent a large share (67%) of total research expenditures in the ICAR/SAU system. In ICAR, crop research received the highest proportion of research expenditure followed by animal sciences and natural resource management (Figure 6). Normative allocation pattern based on value of production indicates (see footnote 12) that crop research should get 51% of resources, followed by animal science (including fisheries) 28% and horticultural crops 21%.[19] Nevertheless, both livestock and horticulture are high growth sub-sectors that might justify slightly more resources than indicated by value of production, although in the case of livestock research, this might be counterbalanced by the fact that livestock research is known to be less location specific with higher spillovers.

[18] The number of scientists working for AICRPs is 3862 (ICAR 1999) and most of them are in SAUs (*ICAR Vision*).

19 These normative commodity-based allocations also include expenditure on research on natural resource management, social science and agricultural engineering, which are common for all commodities.

6. Accountability and Research Impact

A number of monitoring and evaluation mechanisms have been put in place at the national, system, institute and project level to ensure relevance of research and accountability in the use of public funds. At the national level, the Planning Commission and government committees monitor the progress and achievements during preparation of annual and five-year plans. At the regional level, there are eight regional committees comprising representatives of ICAR, SAUs and government departments to assess the status of agricultural research in the region (covering several states), and make recommendations on research priorities. At the institute level, there are management and research advisory committees to oversee administrative and financial matters, advise on research programs, and monitor their progress. In each ICAR institute a staff research council with representation of external experts evaluates research projects.

A more substantive external review of each ICAR institute and each SAU is done by an external review team every five years. The review process covers organizational, management, scientific and other matters relating to effectiveness, efficiency and relevance of the institute. In addition, for SAUs, there is a committee to determine the norms for accreditation and financial assistance from ICAR and to periodically assesses performance of SAUs against these norms.

Through these mechanisms, accountability for the use of public funds is high. However, questions are often raised (more so in recent years) about the effectiveness and impact of the research system. This is in spite of the fact that the Indian research system successfully led a series of technological revolutions in the agricultural sector. Many studies have empirically examined the impact of agricultural research in India by estimating internal rates of return to investments (Table 9). Most have analyzed returns to crop research, individually or for the subsector as a whole. Although there is considerable variation, the average return was about 70%, with a median value in excess of 50%. Interestingly, there is no evidence that the rate of return has declined since the Green Revolution. The studies have also shown that returns to public research investments have been higher than those for public extension or private research (Evenson et al. 1999).

These results provide a convincing case for enhancing public funding to agricultural research. This point has been made repeatedly by research leaders to build the case for the higher budget allocations, particularly during the preparation of the five-year plans. These efforts have achieved some success as demonstrated in the steady rise in public funding to agricultural research over the past two decades, in spite of fiscal discipline adopted by the government during the 1990s.

Finally, it should be noted that high aggregate rates of return may be hiding considerable inefficiencies in the Indian public research system. Traxler and Byerlee (2001) analyzing rates of return to 20 wheat breeding programs across 50 research stations, found that although the aggregate rate of return to wheat improvement research in India over the period, 1978-1991 was estimated to be 55%, eight programs had a negative rate of return when spillins were taken into account. Research output was concentrated in the two strongest programs which generated 75% of all benefits, even though they claimed just 22% of research resources. Clearly there is considerable scope for increasing the overall return on research investment by redirecting money from unproductive research programs.

Table 9. Internal rates of return (%) to research investment in India

	Aggregate analysis	**Analysis for individual crops**	**All**
Mean	75.4	69.9	71.8
Median	58.5	53.0	57.5
Minimum	46.0	6.0	6.0
Maximum	218.2	174.0	218.2
Number of studies	10	18	28

Note: Mode could not be computed as no value is repeated in the observations.

Source: Based on information in Alston et al. (2000) and Evenson et al. (1999)

7. Emerging Policy Issues

Agricultural research policy must respond to a changing agricultural, scientific and economic environment. In the industrialized countries, agricultural research reforms originated from the declining importance of agriculture in the economy and the rapid increases in private research investments. These reforms included separating research funding from research execution, encouraging contestability of funds through competitive mechanisms, improving accountability of research institutions, and shifting near-market research to the private sector (Alston et al. 1999). The new paradigm underscores pluralistic institutional structure, new sources and mechanisms for research funding, organization and management reforms of public institutions, and management of intellectual property (Byerlee 1998).[20] These same reforms are generally proceeding more slowly in developing countries, where there are a large proportion of small scale farmers and the public sector still dominates the research system (Byerlee 1998). Thus the focus of research policy should remain on improving efficiency of the public research system and encouraging participation of the private sector where possible.

Balancing multiple research objectives

The Indian NARS must find a balance among multiple objectives, ranging from traditional food security objectives, to emerging demands to serve a more market oriented economy, meet the needs of more sophisticated consumers, and preserve the environment. Striking a balance between these objectives has major implications for organization of research, prioritization of the research agenda, and management of intellectual property.

Since there are increasing demands on the public sector to provide technologies with characteristics of 'public good' and that address market failures in addressing social and environmental concerns, public research

[20] Also see, a number of papers in special section of *World Development* (Volume 26, Number 6, 1998) on 'Evolution of National Agricultural Research Systems'.

investment in India needs to close the gap with the global average of one percent of agricultural GDP. Also, public research institutions must work closely with key stakeholders to define priorities that address multiple objectives, employing formal research prioritization approaches. This is extremely important when the system is large in size, objectives are conflicting and clients are poor in articulating their research needs. A starting point in this direction would be to carefully track current resource allocations and make necessary adjustments to reflect changing priorities.

Center versus state roles

The distinction between the roles of the center and the states in agricultural research has become blurred over time. In practice, SAUs should have primary responsibility for applied and adaptive research to meet local demands in their respective states, and ICAR should take the lead in strategic research that is relevant to several states, and in those applied research areas where states will tend to under-invest due to spillovers. However, SAUs are generally starved for operating funds and now largely depend on ICAR. A shortage of funding in the SAUs has had adverse effects on human resources development, research infrastructure, and linkages with farmers. There is an urgent need to sensitize policy makers at the state level to the payoffs to investing in research. At the same time, the central government might develop a funding formula that supports the weaker states, but provides incentives to stronger states to increase their funding (e.g., matching grants).

A key role of central research is to generate spillovers to enhance efficiency in state research programs. In some areas, especially crop breeding spillovers are pervasive. The AICRPs provide a mechanism for facilitating such spillovers. For example, Traxler and Byerlee (2001) found that spillovers from the wheat research program of IARI accounted for a large share of benefits of wheat breeding research in India in the post-Green Revolution period.

Toward a more pluralistic system

The modern concept of a NARS emphasizes a pluralistic system of research providers that recognizes the comparative advantages of different providers, and complimentarity that can be achieved by forging close linkages between different actors. The leadership of ICAR has noted these requirements and has taken a number of initiatives to promote such linkages (Mruthyunjaya et al. 2000). However, but effective implementation needs greater awareness down the line. In particular, the growing role of private research and the implications for public institutions are not widely appreciated. Where the private sector can efficiently provide near-market research services with scope for appropriation of benefits, the public sector should be prepared to withdraw and play a complementary role. Private research is stimulated by strategic research support from the public sector, and there are many areas where public-private linkages can enhance the effectiveness of both sectors. Enabling institutional mechanisms, especially IPR protection and capacity within the public sector to manage partnerships, can help develop and sustain these linkages (Hall et al. 2002).

Sustainability of research funding

The Indian public NARS has been relatively successful in increasing government funding for R&E. However, the current funding situation is not sustainable for a number of reasons. First, increased funding has not matched the continuing expansion of the number of R&E institutions, resulting in a steady increase in the share of salary and overhead expenditures at the expense of operating expenditures (Pal and Singh 1997). In ICAR, the salary to operational expenses ratio has increased to 70:30 against a target of 60:40 and the situation is even more serious in the SAUs. Second, although competitive funding has increased, it still accounts for a low share of total funding. Because competitive funding has the potential to enhance accountability, quality and efficiency of the system despite somewhat higher costs in terms of overheads and time of scientists, a higher share of funds should be gradually shifted to competitive funding. Of course, regular block grants must continue in order to maintain and upgrade research infrastructure, and strengthen basic and strategic research.

Finally, new resource generation opportunities such as payments for services by farmers growing high value crops (commercial livestock and fruit crops), income generation through commercialization of technology and services, and contract research with the private sector are emerging and should be tapped. ICAR has set a target of 25% of budget share from these sources by

2020. This will require development of capacities in IPRs and business skills in public research organizations. ICAR has already developed such a policy, and the government has offered matching grants for self-generated income as an incentive.

Challenges of modern science

Although India has developed relatively good capacity in new areas of science, especially biotechnology, these have raised a number of challenges—development of research capacity, biosafety and IPR regulations, and management of public dialogue on controversial issues.

Establishment of biotechnology capacity is relatively capital and human resource intensive. Although it is expected that the private sector will be an active player in biotechnology in India, the public sector will have to play a dominant role, especially for non-commercial agriculture. Therefore, mechanisms to access proprietary technologies by using resources in the public sector, such as germplasm, as bargaining chips and segmentation of markets deserve special attention. Also, given the number of public and private institutions involved, there is much potential for forging public-private linkages to enhance overall impacts. These include sharing of cost and benefits, joint ventures, and management and ownership of intellectual property.

Advances in biotechnology have also blurred the differences between general sciences and the agricultural sciences, requiring close linkages with general science and technology providers. This is more so when major responsibility for promotion of biotechnology in India rests with DBT in the Ministry of Science and Technology.

Given the current debate on biotechnology in India and elsewhere, effective biosafety regulations must be in place that are credible, cost-effective and properly coordinated. This is the single major constraint to application of transgenic technology in India, which still has only just released the first product (Bt cotton), despite many years of research and many products in the pipeline. Finally a dimension often neglected is the provision of information about these new technologies to farmers (Tripp and Pal 2001). Since much of this information is a public good, public institutions will have to take major responsibility of providing information to farmers and educating consumers.

Organization and management reforms in the public sector

The public sector in general in India suffers from centralization and bureaucratization that imposes high transaction costs at all levels. Despite having a certain level of autonomy, the research system is no exception. Although ICAR recognizes these problems and has initiated a number of organizational and management (O&M) reforms, there are still important gaps as well as problems in their implementation. First, institutional rigidities imposed by commodity and disciplinary boundaries restrict the flow of information between hierarchies and organizations in a large system such as India's. The decision to review the functioning of the AICRPs—originally established to forge interdisciplinary and inter-institutional research—was an important step toward addressing these rigidities (ICAR 1999).[21] But much remains to be done to decentralize and devolve power before transaction costs can be reduced to acceptable levels for efficient research management.

Second, there is a growing problem in the quality of scientific human resources owing to inbreeding in the system, especially in the SAU system, and weakening of global scientific linkages. In the 1960s and 1970s, a significant proportion of scientists were educated abroad and Indian scientists were generally well integrated with regional and international networks. This situation has deteriorated significantly with scientists often working in the same institution in which they receive their PhD, and with professional isolation of many scientists. This trend must be arrested through assessment of human resource needs and use of foreign grants and loans for human resources development, and to support participation in international scientific networks and other initiatives. Advances in information and communication technologies also have much potential to foster such linkages and improve access to international literature and

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21The committee has recommended that AICRPs for crop or resources with applicability in different agro-climatic zones of the country should be continued, and other should be phased out or converted to networks. It also made suggestions to streamline the functioning of AICRPs priority assessment and review process.

scientific data bases.[22] At the same time, performance-based evaluation of scientists that is linked with incentives and the reward system is long overdue.

Third, research institutions require much improved accountability through institutionalization of objective and transparent evaluation mechanisms for planning, monitoring and impact assessment of research. Proliferation of research programs has meant that many programs serving small states and agro-ecological zones are inefficient. Much of the inefficiency found in the Traxler and Byerlee (2001) study is due to research programs serving small ecologically- and politically-defined markets, so that even if they are productive in terms of technologies produced, they are only used in a small area. Resource allocation needs to be linked to research planning based on 'bottom up' approaches involving relevant stakeholders and feedback from monitoring and impact assessment. Implementation of such processes has been attempted several times, albeit with varying degrees of success. A prerequisite for its effectiveness is to link planning, monitoring and evaluation with funding decision and with performance evaluation at various levels—the system, institute, project and scientist.

Finally, although successive review panels of ICAR have raised these various concerns and proposed recommended changes, past attempts at reform failed due to lack of financial flexibility and autonomy of ICAR. A package of reforms aimed at enhancing autonomy, improving decentralization and devolution of power, and improved financial management through project-based budgeting is required. Both ICAR and SAUs should commit themselves to such reforms. Support of high level policy makers at both the central government and state government levels is needed to implement a this far reaching reform agenda.

Technology transfer

It is generally agreed that payoffs to agricultural research could be much higher with a stronger research-extension interface. The weaknesses of the

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22 As noted earlier, some efforts in this direction were made under AHRD and NATP, but these need to be streamlined and upscaled.

current system can be attributed to a number of factors: (a) adaptive research and technology transfer is considered to be a less challenging task, and therefore, not many scientists are attracted to it; (b) scientists working for technology assessment and transfer are at a disadvantage since the number of publications dominates performance evaluation criteria; (c) most scientists lack skills to assess farmers' research needs and design appropriate technologies; and (d) scientists lack operating expenses for on-farm research. In addition, supply-driven extension approaches focused on the public sector in India are long overdue for drastic overhaul. Improved accountability to clients through incentive systems in the research system and piloting of more pluralistic and demand-driven extension systems are now being given higher priority as a way to speed technology transfer.

8. Conclusions

This paper has examined policy, funding and institutional issues relating to agricultural research in India within the context of rapid changes in the scientific, economic and social environment. The Indian agricultural research system has a long and distinguished history that evolved from a decentralized system in the imperial research system into a highly centralized system created in the post-independence period to respond to the food crisis of the 1960s. With increased food production as the driving force, the system grew rapidly, through both central and state fiscal appropriations. The impacts of this investment were impressive, as India became food self-sufficient, and numerous studies documented high payoffs to the investment.

In the 1990s, new challenges have arisen that are forcing changes in the organization and funding of research in India. Food security is now only one of several goals of the research system. Globalization and rapid developments in science, privatization and liberalization of the economy, and challenges of sustainable resource management and diversification are now placing new demands on the system.

Clearly a strong central research system is still required but the role of this system must evolve to focus on upstream and strategic research to generate spillovers at the national level. Other actors will play an increasing role in the system, especially the SAUs, general science research institutes, and the private sector. The articulation of actors in this more institutional diverse and decentralized NARS is evolving. Inevitably there will be tensions that must be resolved, such as the effort to organize research along agro-ecological lines to enhance efficiency, while at the same time attempting to attract funding at the local level within the context of politically-defined administrative boundaries.

Even with a rapidly expanding private sector in agricultural research, the public sector will continue to play a dominant role for many years to come. However, the efficiency and effectiveness of the public sector will depend on critical policy changes and institutional and management reforms to drastically improve its performance. These reforms must evolve around autonomy, decentralization, financial flexibility, and accountability. The proposed reforms are not new but their implementation must be streamlined at two levels. First, there must be greater realization at the policy level of the need for reform in order to keep pace with global changes. Second, the public research system requires an internal paradigm shift that links funding to performance of research providers, improves relevance of research through participatory approaches, and institutes a performance-based incentives and reward system. Finally, there is a need for much greater awareness of the development, protection, commercialization and application of intellectual property and technologies in enhancing research impact and access modern scientific tools.

Some important lessons can be learnt from the Indian NARS. First and foremost is that political commitment through sustainability of public funding is essential for developing an effective NARS. The Indian system has ably demonstrated this over the long term, despite the transition at Independence and changes in governments of different political ideologies during the post-independence period. However, as the system grows in size and complexity, a number of organizational and management problems emerge. The system has also shown that these problems could be addressed if an appropriate management system and leadership is in place, and there is a willingness to learn from past as well as contemporary institutional developments in research systems globally.

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Appendix A1. Intensity of public funding to agricultural R&E in India, 1991-1999

	Local currency units (Rupees, M)		US$, M	1999 PPP, M
	Current prices	1999 prices	Current prices	
1991	7137.0	14931	398.7	1726.1
1992	7718.0	14079	315.0	1627.6
1993	8329.4	13997	272.2	1618.1
1994	9599.6	14741	306.7	1704.2
1995	11063.2	15514	352.3	1793.6
1996	12149.8	15671	363.8	1811.7
1997	13663.1	16359	384.9	1891.2
1998	15156.9	17051	407.4	1971.2
1999	19603.9	20246	465.7	2340.5
2000	25023.0	25023	577.9	2892.8

Note: Data are actual expenditure, except for 2000 which are revised estimates.

Source: Data in current LCU compiled from MoF and RBI, and other columns computed by the authors.

Appendix A2. Annual international lending for agricultural R&E in India

Period	USAID	World Bank	Total	
	US$, M		US$, M	1999 PPP, M
1963-65	3.24	-	3.24	6.15
1966-77	2.84	-	2.84	7.10
1978-85	4.94	17.15	22.09	57.76
1986-91	4.12	27.46	31.59	106.13
1992-97	-	7.78	7.78	36.51
1998-2002	-	37.94	37.94	192.94

Note: Data may not tally exactly with those in Figure 1, as these are average figures.

Source: USAID data from Alex (1997) and World Bank data calculated from World Bank

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