Module 2: Investments in Agricultural Science and Technology

Higher rates of growth in agricultural productivity are essential to promote broad-based economic growth, reduce rural poverty, and conserve natural resources. Productivity growth, in turn, is based largely on the application of science, technology, and information provided through national agricultural research and development (R&D) systems—not just public organizations, but all organizations that generate, share, import, and use agricultural knowledge and information.

Rationale for Investment

Investment in agricultural science and technology (S&T) has been critically important to past growth performance, and it is likely to be even more important for achieving future global development priorities, especially the Millennium Development Goals (MDGs) of halving poverty and hunger by 2015. In 2000, the total global spending on agricultural R&D was $36.5 billion (Pardey et al., forthcoming). Regional variation in research investments is considerable (box 2.1). The challenge in deciding future investments in agricultural R&D is to maintain past productivity gains, while supporting technological innovation in more diverse agricultural systems that will differentiate products and add value by processing, which will enable rural producers to capture a larger share of the gains. Accordingly, the World Bank’s current rural strategy, Reaching the Rural Poor, places high priority on investments in agricultural S&T.

Box 2.1 Regional trends in agricultural R&D spending

During the 1990s, developing countries undertook more of the world’s public agricultural research than developed countries. The Asia-Pacific region has continued gaining ground, accounting for an increasing share of the developing country total since the early 1980s. In 2000 just two countries in that region, India and China, accounted for 39 percent of the entire developing world’s public expenditure on agricultural research and development (R&D). In stark contrast, Sub-Saharan Africa has continued to reduce expenditure on agricultural R&D, accounting for only 11.4 percent of the developing country total in 2000. Among rich countries, public agricultural R&D is increasingly concentrated among just four countries—France, Germany, Japan, and the USA—which account for two-thirds of agricultural R&D spending in rich countries.

Of the global spending on agricultural R&D—amounting to US$36.5 billion—about 37 percent comes from private firms, which direct 94 percent of these resources to developed countries. In the Asia-Pacific region, 8 percent of agricultural research spending is private, compared with only 2 percent in Sub-Saharan Africa.

Source: CGIAR Science Council 2005
Growth and competitiveness. S&T underpin the innovation that is needed to promote economic growth and enhance competitiveness. Agriculture is a critical sector in many countries, especially low-income countries. Although complementary investments in policy reform, markets, and institutions are necessary, investment in S&T is a key element in enhancing a country’s competitive advantage by reducing production costs, improving product quality, and generally increasing efficiency along the commodity chain.

Poverty reduction. Investment in agricultural research has major impacts on poverty reduction through direct effects on producer incomes, indirect effects on consumer welfare through lower food prices, employment and wage effects, and growth-induced effects throughout the economy (box 2.2). Studies by IFPRI on the impacts of public investment in India and China show agricultural R&D to have higher impacts on poverty reduction compared to most other public investments, second only to investment in education in China and rural roads in India (Fan, Zhang, and Zhang 2000; Fan, Hazell, and Thorat 1999). Studies show that in low-income countries, a 1 percent increase in agricultural yields leads to a 0.8 percent reduction in the number of people below the poverty line (Thirtle, Lin, and Piesse 2003). Over the long term, effects on food prices are especially important, as food is a large share of the expenditures of poor households. Employment and wage effects of labor-intensive production and value-added processing are especially important to poor people, who depend relatively more on wage labor (box 2.3).

Food security. By 2020, IFPRI projects that food needs in developing countries will increase by nearly 600 million tons, which is equal to one-third of current world food production. To ensure global food security, continued investment is needed to increase productivity and strengthen the environmental sustainability of production systems. Investments in technology must also enhance household food security by increasing the productivity of household food production, smoothing the seasonal availability of food, mitigating the effects of drought, and improving the nutritional content of food.
**Environment and natural resources.** Future increases in agricultural productivity must come from intensification of agricultural production, rather than from the exploitation of additional natural resources. Agricultural systems must use natural resources more efficiently and repair past damage to ecosystems. Success depends on applying scientific knowledge, developing farmers’ skills, and devising a policy framework to improve resource use and conservation.

**Public goods.** Many products of agricultural research are public goods that the private sector lacks incentives to produce. Small-scale farmers with limited purchasing power are not organized to finance research. Private firms, with limited opportunity to appropriate profits from provision of technologies, will not invest sufficiently in research. Because of these market failures and because of long-term risky payoffs, the public sector funds most agricultural research, especially in developing countries (table 2.1.). Although private funding for agricultural research is expanding rapidly, part because of the application of stronger intellectual property protection, private research often relies on knowledge provided by publicly funded research.

**Economic returns to investment in science and technology.** Studies consistently show high returns to investments in agricultural research in developing countries, averaging over 40 percent (table 2.2). Rates of return tend to be higher for research in industrial countries and for commodities with short production cycles. Paradoxically, despite evidence of high returns, funding for agricultural R&D is stagnating in many countries, and funding for agricultural education and training (AET) is declining (box 2.4).
Table 2.1 Public and private agricultural research and development expenditure, circa 2000

<table>
<thead>
<tr>
<th>Public</th>
<th>Private</th>
<th>Total</th>
<th>Public</th>
<th>Private</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing countries</td>
<td>12,819</td>
<td>869</td>
<td>13,688</td>
<td>93.7</td>
<td>6.3</td>
</tr>
<tr>
<td>Developed countries</td>
<td>10,191</td>
<td>12,577</td>
<td>22,767</td>
<td>44.8</td>
<td>55.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23,010</strong></td>
<td><strong>13,446</strong></td>
<td><strong>36,456</strong></td>
<td><strong>63.1</strong></td>
<td><strong>36.9</strong></td>
</tr>
</tbody>
</table>


Table 2.2 Estimated rates of return to investment in agricultural research (based on studies carried out from 1953 to 1997)

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of estimates</th>
<th>Median rate of return (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>188</td>
<td>34</td>
</tr>
<tr>
<td>Asia</td>
<td>222</td>
<td>50</td>
</tr>
<tr>
<td>Latin America</td>
<td>262</td>
<td>43</td>
</tr>
<tr>
<td>Middle East/North Africa</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td>All developing countries</td>
<td>683</td>
<td>43</td>
</tr>
<tr>
<td>All developed countries</td>
<td>990</td>
<td>46</td>
</tr>
<tr>
<td>All</td>
<td>1,772</td>
<td>44</td>
</tr>
</tbody>
</table>

Source: Alston et al. 1998

Box 2.4 Trends in agricultural education and training in Africa

Total investments in post-secondary agricultural education and training (AET) in Africa have declined significantly during the past two decades. Domestic investment in AET fell off in the 1990s, largely owing to economic structural adjustments and reduced public budgets. The period from 1985 to the present has been characterized by efforts to downsize and restructure public services, to privatize state agricultural enterprises, and to create new forms of public/private partnerships. In the process, two new drivers of agricultural policy—agricultural market liberalization and governance decentralization/democratization—are reshaping the labor markets for trained agriculturalists and associated professions.

International development assistance to Africa for AET waned in parallel with the reductions in governmental funding for agricultural capacity building. Several factors account for the decline, including the end of the Cold War, a shift in donor priorities that favored basic education and health, and the faulty assumption that the green revolution in rice and wheat had solved most of the important production problems. Over this period, donor support for the three components of the agricultural knowledge triangle (education—research—extension) became highly imbalanced, with agricultural education receiving little assistance from many of the leading donors.

Recent literature and project experience indicate that human capital now constitutes a major constraint to Africa’s agricultural development. Both suggest that greater attention should be given to strengthening institutional capacities for technical and professional education for the agricultural sector, especially at the post-secondary level. In response, the World Bank is likely to increase its financing for post-secondary agricultural education and training in Sub-Saharan Africa.

Source: World Bank 2005
Past Investment Activity

In the early 1980s, as the Bank recognized the major contribution of R&D to increasing agricultural production, lending for agricultural R&D increased rapidly to become a priority in the agricultural loan portfolio.

Since 1980, the Bank has provided over US$2.5 billion for agricultural research in about 100 countries (figure 2.1), accounting for a large share of all external support for agricultural research in developing countries. In addition, the Bank is one of the leading contributors to the Consultative Group on International Agricultural Research (CGIAR), granting US$50 million annually to the system. Despite the high priority accorded to agricultural S&T in the Bank’s rural strategies, lending has fallen sharply since 1998. This trend is especially marked in Africa and South Asia, where past investments often failed because borrowing countries had not committed to a program of sustainable institutional development. However, since 2004, lending in agricultural research has again increased, and annual investments exceed US$70 million.

Figure 2.1 Lending for agricultural research, 1981-2005

World Bank support to agricultural technology programs has evolved over time. A “bricks and mortar” period up to the early 1980s emphasized expanding public sector research through investment in physical infrastructure, equipment, and human resource development, in many cases to create centralized national agricultural research organizations/institutes (NAROs/NARIs). From the late 1980s, emphasis shifted to improving the management of existing public sector research organizations through better planning, improved financial management, greater accountability, and increased relevance of programs to clients. In the mid-to-late 1990s, the instability and inefficiency evident in many public research organizations (box 2.5) led to an emphasis on developing institutionally pluralistic agricultural knowledge and information systems (AKISs) with greater client participation and financing. The approach has further evolved during the past five years towards supporting agricultural innovation systems.
Box 2.5 Common problems in public research organizations

Common problems identified in reviews of World Bank support to agricultural research result from strong path-dependency in institutional development and slow institutional and policy change:

- Lack of consensus on a strategic vision for public sector research organizations and the evolution of the research system.
- Ineffective leadership for many research organizations, resulting in internal management problems and lack of political support and funding for research.
- Continued emphasis on building centralized national agricultural research organizations/institutes (NAROs/NARIs) at the expense of fostering a public-private system, including universities.
- Difficulties in establishing an appropriate legal and governance framework for research organizations to provide the efficiency and flexibility needed in managing financial, physical, and human resources.
- Loss of highly qualified scientific staff, and difficulties in recruiting the best and the brightest.
- Weak links between NAROs and other research providers, clients, technology transfer agencies, and development organizations.
- Weak accountability to clients and funders.

Source: Authors

A 1997 evaluation of World Bank lending for agricultural research from 1980 through the early 1990s suggested that portfolio performance should be rated “unacceptable” (Purcell and Anderson 1997). The evaluation recommended that the Bank provide comprehensive assistance for research systems only when the borrower makes a clear commitment to fund the system adequately and to adopt sound management principles.

Since 1997, the Bank has supported agricultural R&D within the framework of the development of effective and efficient AKISs that “link people and institutions to promote mutual learning and generate, share, and utilize agriculture-related technology, knowledge, and information” (FAO/World Bank 2000). Such a system integrates farmers, agricultural educators, researchers, and extensionists to harness knowledge and information from various sources for improved livelihoods (figure 2.2). Farmers are at the heart of this knowledge triangle and, along with other rural people, must be central partners. Investments in this system must be long term, focused on support to increasing rural innovation and competitiveness, and follow a set of guiding principles (box 2.6).
Box 2.6 Guiding principles for investment in research systems

The World Bank and Food and Agriculture Organization (FAO) developed the following guiding principles for agricultural knowledge and information systems (AKISs) program design:

**Defined role for the public sector.** Research investments need to target public funding for the provision of public goods so that investments are:
- Made within a sound policy framework.
- Based on clear national strategies that articulate a long-term vision and national policies, plans, and objectives for research.
- Economically efficient with benefits and expected outcomes that justify the investment.
- Equitable with research results available to the poor and minority groups.

**Strengthened demand for services.** Strengthening demand is critical to improving their efficiency, effectiveness, and sustainability, and it requires that investments be:
- Demand-driven, responding to farmers’ needs and interests and involving clients in program governance, priority setting, and evaluation.
- Participatory, empowering local people to solve problems and mobilize resources.
- Based on subsidiarity, with responsibilities devolved to the lowest possible level of government consistent with competency, comparative advantage, and efficient use of funds.

**Improved quality of services.** Management improvements essential to improving research execution require that research programs are:
- Accountable for use of funds and for results, with incentive structures that ensure assignment of qualified staff who are given adequate support and held responsible for results.
- Relevant to the needs and resource constraints of different categories of clients, balancing objectives of profitability, productivity, and sustainability.
- Pluralistic, involving a range of institutions with different comparative advantages undertaking different research activities.
- Well monitored and evaluated to ensure that they are results-oriented; account for impacts on human, social, and environmental capital; and demonstrate cost effectiveness.

**Based on a sustainable system.** Institutional sustainability depends on principles listed above and on financial sustainability and development of institutional capacity through investments that:
- Develop the human and social capital necessary for clients and local institutions to be capable of continuous learning and problem solving.
- Are cost-shared by major stakeholders based on agreed criteria, including ability to pay for and use research results.
- Develop political support from stakeholders as a basis for securing future financing.

Source: FAO/World Bank 2000

More recently, the Bank’s agricultural research and extension approach has moved towards the concept of “agricultural innovation systems.” An agricultural innovation system (AIS) is made up of the institutions, enterprises, and individuals that demand and supply knowledge and technologies and the rules and mechanisms by which these different agents interact. The ultimate objective of a well-functioning AIS is to serve the needs of the economy by achieving better integration of the S&T infrastructure with production needs, by increasing private sector participation in technology development, and by developing stronger linkages between producers, industry, universities, and research institutions. The focus of an AIS is not on the science suppliers but on the
totality of different actors and practices that are involved in innovation, application, and generation of growth (ARD 2006). The China Agricultural Technology Transfer Project, initiated in 2005, is an example of a project that already applies this concept and brings together various public and private sector representatives along with farmers and their associations.

**Future Directions for Lending**

*Promoting pluralistic systems.* Public research agencies will remain central to providing coherence to and facilitation of many research efforts.¹ Strategies, however, must enhance, not restrict, participation by the full range of research providers, including universities, private firms, NGOs, and farmer organizations. Full participation will require:

- **Defining public and private roles.** Effective research systems incorporate both public and private organizations, each filling the role for which it has an advantage. Public funding is critical to provide public goods and to establish the rules of the game that encourage an efficient overall research system. Not all countries can afford extensive public systems, but all must have institutional capacity to provide rural people access to benefits from advances in S&T, whether developed at home or elsewhere. Efforts to promote greater private sector participation in developing country research systems have mixed results but remain a long-term priority for science policy.

- **Improving science and technology policy.** Many countries have invested substantially in technology development, while restricting imports of “free” technology available through access from abroad (so-called “spill-ins”). Sound policy frameworks for innovation—IPRs,² biosafety regulations, genetic resources policy, and seed and input market regulations—are prerequisites for scientific organizations to function efficiently and for enabling developing countries to reap the benefits from global advances in S&T.

- **Delinking funding and execution.** Decisions on financing public goods can often be separated from responsibilities for producing them, and even when public financing of services is justified, the private sector (for-profit or not-for-profit) is often more efficient in delivering the product. Initial experiences show that competitively contracting S&T services divides responsibility between the public and private sectors and improves the quality, accountability, and impact of services.

- **Promoting partnerships.** An efficient and effective division of labor for S&T depends on partnerships to integrate the various players into an overall system. Partnerships allow for specialization, exploit institutional comparative advantage, and may reduce costs. Partnerships are often particularly useful in linking institutions with differing

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¹ See the Agricultural Investment Note (AIN), “Strengthening Public Research Institutes.”

² See the AIN, “Design and Implementation of IPR Regimes to Support Plant Breeding in Developing Countries.”
competitive advantages for work at different levels of the research continuum, as with international research centers for strategic research, and NGOs and producer organizations for adaptive research. Effective public-private partnerships have generally required (1) a facilitating organization and a facilitator with a mandate and ability to promote the partnerships; (2) a visionary and innovative leader in the private sector with credibility and recognition within the sector; (3) research organizations with goodwill and recognition that offer knowledge and technological options relevant and responsive to the demands of the value chain; and (4) researchers with good knowledge of the value chain and available technological options, and with an aptitude to relate to the private sector (Rajalahti et al. 2005).

**Strengthening demand for research products.** Past investments in S&T have focused mostly on the supply of research products. Farmers, especially poor farmers, generally lack the ability to participate in funding, priority setting, execution, and evaluation of research programs. To be effective and sustainable, research systems must become more responsive to clients’ demands and interests and become more accountable to clients by:

- **Encouraging participation of various actors.** Empowering farmers as purchasers, providers, and cofinanciers of research helps ensure that research systems respond to their needs. Rapid appraisals and participatory on-farm research draws on farmer knowledge and provides opportunities for them to participate fully in planning, executing, and evaluating research. Farmer, private sector and other stakeholder participation on research governing boards and advisory panels can have real influence over research decisions and priorities. Participation of women farmers is particularly important, given their crucial role in rural production systems; the special constraints under which they operate (for example, time constraints); and their range of activities and enterprises, including marketing, agro-processing, and food storage.

- **Decentralizing and deconcentrating research.** Decentralization strategies being pursued in many countries lead to complex trade-offs in the case of agricultural research. Deconcentrating research involves establishing research facilities under a central research institute but located in different agro-ecological zones or political units (for example, provinces). Decentralization devolves funding, governance, and administrative responsibilities to regional, state, or local governments. Both approaches can bring scientists closer to clients and better focus research on local problems and opportunities, but they can also result in inefficient and fragmented systems that fail to take advantage of important economies of size and scope in much R&D. However, where possible, decentralized adaptive research is desirable, by ultimately allocating funding to users, who then contract needed research services (figure 2.3).
Sustainability of R&D investments. Many public research organizations have suffered financial crises as declining budgets have led to minimal operating budgets and salaries and incentives have eroded. Financing a recurrent cycle of expansion and decline of public research organizations under consecutive Bank projects is inefficient. Instead, greater attention must be given to:

- **Right-sizing.** Sustainability demands that national governments provide adequate budgetary support to agricultural R&D and “right-size” research organizations to the resources available, using funds saved for operating costs and for paying scientists competitive salaries. Without evidence of government commitment to such policies and reforms, external investment directed to public research organizations is inefficient and unsustainable. Agricultural R&D must receive priority in national budgets.
• **Ensuring sustainable financing.** Public investment in agricultural research in developing countries must increase sharply in order to promote a dynamic and competitive agricultural sector (figure 2.4). In almost all cases, government must provide core funding for public research institutions (or universities) that maintain a core scientific capacity to undertake long-term public good research.

**Figure 2.4 Agricultural research intensity by region: public sector only**

*Source: Pardey and Beintema 2001*

• **Improving management.** Many research organizations are unproductive, suffering from poor leadership, onerous bureaucratic procedures, political interference, low morale, and weak links to clients. Reforms are needed, and they require long-term support for institutional development to address problems of inadequate operating funds, weak human resource policies, and the absence of performance incentives and clear priorities. In many cases, it will be necessary to create flexible and efficient autonomous research organizations, run along private sector lines, with independent governing boards representing key stakeholders.

• **Accountability.** Reforms must make research institutions and researchers accountable to clients and funding agencies. Client cofinancing of research, participation in governance bodies, and participatory evaluation are central to ensuring accountability. Such reforms should help to develop a local political constituency for sustainable organizations. Building a local constituency also depends on better evaluation of impacts and diffusion efforts to increase public awareness of these impacts.

*Changing research priorities.* Research systems must reconcile national priorities, derived from national development strategies and policies, with the demand-driven and market-oriented priorities arising from clients. Generally, however, future investments are likely to give priority to several areas of global and national importance:

• **Improved poverty targeting.** With the private sector increasingly serving the commercial farming sector, public funding must focus more sharply on the poor.
Public R&D organization must carefully set priorities in terms of commodities, regions, and types of technology important to the poor, combined with bottom-up processes of participatory priority setting, executing, and evaluating research. Poverty targeting leads to quite different strategies for different types of farmers (table 2.3). Gender is relevant also in targeting S&T investments to reduce poverty: in developing countries, a large share of poor farmers are women, and their numbers are increasing as men migrate to off-farm employment.

- **Aligning R&D to market trends.** Improved technology and information, especially at the postharvest stage, is essential to orient farmers to market needs, reduce costs, improve product quality and food safety, meet more demanding grade and standard requirements, and diversify to higher-value and niche products. Nontraditional exports (for example, horticultural exports, cut flowers, and organic foods) offer potential for major increases in rural employment and incomes, but they frequently require substantial research and an entirely new base of knowledge and skills, which generally are not available locally.

- **Natural resources and environmental conservation.** The degradation of natural resources and public concern over environmental issues are shifting research priorities and funding toward broader issues, many of them global in nature, such as sustainable use of land, water, forests, and biodiversity; adaptation to climate change; pesticide safety and residue minimization; livestock waste management; water quality preservation; and watershed protection. Increasing opportunities are available for agriculture to provide environmental services through carbon farming and conserving biodiversity. Success in meeting these challenges requires sharply increased skills in research on natural resource management (NRM), social sciences, and environmental issues.

- **Health and nutrition.** The dearth of knowledge about the health of the rural population, the impact of health problems on the productivity of rural labor, and the spread of HIV/AIDS in the developing world has brought health and nutrition issues to the forefront in the recent past. The demand for knowledge along these lines will grow as more is learned about the nexus of agriculture, health, and nutrition and as new tools are available to advance this agenda (for example, molecular biology has already demonstrated the potential to create vitamin- and micronutrient-enriched food crops.

**Social science and policy research.** Many research systems find it a perennial challenge to maintain the capacity for socioeconomic research, but this capacity will be needed more than ever to support the development of public policy, poverty reduction strategies, a more market-oriented agriculture, and natural resource management strategies. Inclusion of this expertise in interdisciplinary teams is also essential to help target the natural sciences and to optimize application of technologies.
Table 2.3 Strategies for enhancing poverty reduction through agricultural research, by farm type

<table>
<thead>
<tr>
<th>Sector</th>
<th>Direct impacts</th>
<th>Indirect impacts</th>
<th>Major R&amp;D actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial farmers</td>
<td>Increase micronutrient content of food to provide nutritional benefits</td>
<td>Increase productivity to reduce food prices for nontradable food staples</td>
<td>Private agribusiness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Generate employment in high-value industries, processing, and handling</td>
<td>Public regulatory framework</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Producer/trade organizations</td>
</tr>
<tr>
<td>Small-scale, market-oriented farmers</td>
<td>Diversify production to increase value-addition and high-value crop/livestock production</td>
<td>Increase agricultural productivity to stimulate overall economic growth</td>
<td>Public research</td>
</tr>
<tr>
<td></td>
<td>Develop technologies to reduce production risks</td>
<td>Diversify production systems to generate employment</td>
<td>Public-private partnerships</td>
</tr>
<tr>
<td></td>
<td>Strengthen producer organizations to improve demand for research and build human and social capital</td>
<td>Increase productivity to reduce food prices</td>
<td>Producer organizations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase value-added</td>
<td>NGOs</td>
</tr>
<tr>
<td>Subsistence-oriented farmers</td>
<td>Increase productivity, reduce production risks, and improve food storage and utilization</td>
<td>Build human and social capital necessary to address a range of livelihood opportunities</td>
<td>Public research</td>
</tr>
<tr>
<td></td>
<td>Reduce labor requirement for tasks performed by women and the very poor</td>
<td></td>
<td>Producer and community organizations</td>
</tr>
<tr>
<td></td>
<td>Encourage market access for high-value crops/livestock</td>
<td></td>
<td>Women’s groups</td>
</tr>
<tr>
<td></td>
<td>Improve natural resource management (NRM)</td>
<td></td>
<td>NGOs</td>
</tr>
</tbody>
</table>

Source: Byerlee and Alex 2002
**Accessing new knowledge.** Developing countries will need to make use of the latest advances in S&T to address intractable problems in agricultural production and exploit new opportunities. Country size and level of technological development will shape different strategies for different countries, as they seek to overcome both scientific and institutional constraints associated with the use of new technologies. Key strategies to tap benefits from new technologies include:

- **Investing in advanced science and technology.** Biotechnology and information and communications technologies provide new tools to address the needs of the rural poor. To a large extent, developing countries are not sharing in the benefits from these advances, thus creating “molecular” and “digital” divides. While strategies to access these new technologies will vary depending on the science capacity and level of development in a given country, all countries will need to strengthen their policy and regulatory frameworks for IPRs, biosafety and food safety, and identity preservation (that is, the traceability of products from farm to consumer).

- **Strategic alliances and partnerships.** All countries can benefit from regulatory frameworks favoring technology spill-ins, public-private partnerships, and regional and international alliances. Links to the CGIAR enable many developing countries to tap sources of new knowledge and innovations. Because many commodities are not covered by the CGIAR (for example, horticultural crops, tropical fruits, and coffee), research organizations must seek a broader range of partners. Regional research initiatives led by regional or subregional agricultural research organizations are especially important in sharing the cost of research among many small countries.

- **Managing IPRs.** Proprietary technologies are important in providing incentives for private sector research investments, but the results of such investments do not necessarily benefit the poor. IPR systems in plant breeding must be tailored to the conditions of each country if they are to have their intended effect. Even within a single country, the requirements and conditions are not uniform, and countries may consider legal options that address this variability. Public research institutions need the capacity to form partnerships or contractual arrangements to use proprietary scientific knowledge and to patent their own research in ways that will protect the interests of resource-poor farmers.³

- **Strengthening uptake pathways.** Linear systems of research that pass recommendations to extension, which then transfers them to farmers, are largely obsolete. Agricultural innovation systems effectively bring together the various actors involved in different stages of knowledge and innovation generation, management, and use. This web of interaction also allows farmers to participate in identifying research needs and to seek advisory and information services from a variety of sources. R&D organizations must use a range of potential uptake pathways or institutional mechanisms to provide research results to users.

³ See the AIN, “Design and Implementation of IPR Regimes to Support Plant Breeding in Developing Countries.”
• **Commercializing research products.** Public research institutions increasingly will rely on private sector market mechanisms to disseminate research products. Establishing links early in the research process is often critical to ensure that appropriate partnerships are formed and that the final research product can be used. Active facilitation of partnerships and clustering of industries and R&D organizations into science parks may facilitate commercialization of public sector innovations. The success of industrial clusters has varied greatly and seems to relate to the level of critical mass in the cluster, the diversification of the companies, the economic incentives provided, and the intensity of interaction between R&D bodies and business communities.

• **Linking to demand-driven extension systems.** Decentralized extension services accountable to local user groups should facilitate client “purchase” of research services and products that respond to their needs. Matching grant programs for farmer and community groups can allow them to test and disseminate new technologies. A number of countries have introduced competitive grant programs to provide such alternatives to farmer groups.

**Scaling Up Investments**

Investments in S&T to support rural development remain a priority for the World Bank Group. Many research reforms—competitive funding, contractual mechanisms, user funds, decentralization, science parks, facilitation of collaboration on innovations, and regional and international partnerships—have promise. However, experience with most of these initiatives is still limited, and more in-depth evaluation is required prior to wider scaling up. Biotechnology is also a key investment priority, but monitoring of risks, both actual and perceived, must be an integral part of Bank support. Complementary investments in agricultural education have been neglected, but they are essential to ensure a new generation of agricultural scientists and leaders.

Agricultural investments must be tailored to the needs and conditions of individual countries, and the sustainability of agricultural investments is a continuing challenge. Long-term commitments, through adjustable program lending and sequential operations, are important to build institutional capacity and foster the sustainability of AKISs. The level of financing provided might be less per year than in the past but continue over a longer period.

Increased agricultural S&T sector analysis and policy dialogue are needed in many countries that have yet to commit to reforming their agricultural research systems. In these cases, policy dialogue will provide options for moving forward with reforms, before Bank support to agricultural S&T is renewed. Better monitoring and evaluation of research programs at all levels is essential to improve program management and impacts, enhance scientific quality, and demonstrate results to funding agencies (Rajalahti et al. 2005).

Finally, several important gaps in established good practice need to be addressed in future work, including new approaches to promoting innovation and research-extension linkages.
in decentralized systems, public-private partnerships and commercialization of research products, decentralizing research, involving producer organizations in financing and executing research, and multicountry research investments.

**Selected Readings**

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.


**References Cited**


This overview was prepared by Derek Byerlee, Gary Alex, and Eija Pehu, with input from the Sustainable Agriculture (SASKI) Thematic Team of the Bank. Peer review comments were provided by Marie-Hélène Collion, Howard Elliott, Juergen Voegele, and Jacob Kampen. The overview was updated by Riikka Rajalahti and Eija Pehu.
Competitive Research Funds

Competitive research funds are being introduced in many countries for financing agricultural research in ways that mobilize available research capacity, stimulate scientific creativity, and promote efficiencies in the research system. Competitive research funds can be an effective mechanism for allocating resources for agricultural research and can drive reform of the overall research system. High-quality review, administrative efficiency, and transparent processes are essential to program credibility, but most programs have yet to develop sustainability strategies.

Many countries are seeking to reform national agricultural research systems that have become unproductive owing to insufficient operating funds, incentives, and flexibility. Competitive research funds are financing mechanisms that can marshal available scientists for work on key problems, develop institutional linkages and research capacities across organizations, and link scientists with users of new technologies.

Competitive Research Grants Programs

In competitive research grants programs (CRGPs), research providers are selected on a competitive basis, using calls for proposals and scientific peer review to allocate funding. CRGPs are often linked to the establishment of an agricultural research fund, which is open to a variety of potential contributors who may wish to finance specific research or technology transfer activities through the fund. CRGPs complement “core” funding or “block” grant funding, in funds are allocated annually to specified public research organizations for their core research programs, infrastructure, and human resources.

Benefits

CRGPs are flexible and can be used to accomplish objectives that are difficult to achieve through block funding. CRGPs can restrict funding to specific research topics (for example, rice); types of research (for example, adaptive on-farm research); projects requiring collaboration between organizations or with farmers; or research within a specific region or discipline (box 2.7). Their flexibility makes CRGPs a useful tool in building national agricultural research systems, as they can:

- Mobilize the best available scientists, including those in universities and the private sector, for work on specific high-priority projects.
- Develop a pluralistic research system by providing operating costs to better utilize available human and physical infrastructure from a wide range of institutions.
- Promote research partnerships and collaboration between different organizations, disciplines, or countries.
- Make research more demand-driven by involving clients in setting priorities and financing, executing, and evaluating research.
- Increase total research funding by mobilizing funds from farmers, industry, and other sources.
- Improve research quality and innovation by selecting projects based on rigorous technical review of scientific merit, sound work-plan, and expected results.
Box 2.7 Ecuador: competitive grants

The Program for Modernization of Agricultural Services in Ecuador finances a competitive research grants program (CRGP) that has funded 112 research projects. The program has supported strategic work on innovations to open new export markets through controlling fruit fly (in cherimoya, guava, zapote, and other Andean fruits), decreasing production costs for new export products (such as snails, tree tomatoes, babaco, mushrooms, and artichokes), and controlling disease and insects in traditional exports crops (banana, cacao, and coffee).

The program introduced a new research culture and brought new organizations into the research system. Research projects are being executed by 45 public and private organizations, with most projects directly linked to potential users of the technologies. The government contracted program management to a private agency to develop procedures and ensure objectivity in program operations. Research project costs averaged US$116,000, of which 54 percent is financed by grants and 46 percent by executing agencies, mostly through in-kind contributions. By leveraging of cofinancing for research projects, the program helped increase national research funding by 92 percent to approximately 0.54 percent of agricultural GDP.

Source: World Bank internal documents

Policy and Implementation Issues

Success with competitive funding generally requires realistic expectations, clear priorities, efficient and transparent program management, and involvement of stakeholders in setting priorities. It is important to be especially clear about objectives and desired long-term outcomes and to design CRGPs accordingly.

Base for competition. CRGPs require sufficiently large numbers of potential research providers to ensure a competitive environment and adequate expertise for peer review and monitoring activities—a problem in small countries. CRGPs must also enjoy strong support from research organizations and government ministries (box 2.8). Protection from political interference in resource allocation is crucial to maintaining program credibility.

Box 2.8 Brazil: Embrapa competitive grants scheme

In 1997 the Brazilian Agricultural Research Corporation, Embrapa, launched a competitive grants program to diversify funding for research and stimulate efficiencies and change in the national research system. World Bank financing (two-thirds for competitive grants and one-third for capacity building) supported a program targeting small-farm production technology, advanced technologies, natural resource management (NRM), and agribusiness.

By 1999, the program had funded 69 projects (212 subprojects) from 506 proposals submitted in 5 calls for proposals. Several factors facilitated the fast start-up. Brazil has a large agricultural research establishment with 5,500 full-time researchers distributed equally in Embrapa, state research agencies, and universities. The country had considerable experience with competitive research programs, although not in the agricultural sector. The staff of the program secretariat traveled extensively to solicit stakeholder views on the program and to publicize the program and procedures for grant proposals.

Source: Reifschneider, Byerlee, and de Souza 2000
Limitations. Competitive grants can be an important element of overall research funding, but they are inherently unstable and do not provide the continuity required for some types of research programs. CRGPs should therefore be used to complement core funding, which provides infrastructure, human resource development, salaries, and support for long-term research programs requiring continuity (such as crop breeding).

Priority setting. Competitive funding can promote demand-driven research by involving key stakeholders, especially users, in setting priorities, formulating projects, and screening proposals. However, purely demand-driven approaches with individual proposals considered in isolation can lead to a fragmented portfolio of projects that lacks synergies between activities and does not address national priorities. Important technological or market opportunities can be lost because of farmers’ lack of information and preference for short-term results.

Program sustainability. Most programs financing CRGPs envision them as permanent features of the agricultural research system, but permanence requires mechanisms to ensure institutional and financial sustainability. The institutional structure for a CRGP must be efficient and transparent if it is to win continuing support from researchers and clients. An independent, influential, and respected governing board can help defend the program and sustain its institutional vitality.

Costs and cofinancing. Introducing CRGPs can involve high upfront costs—although established funds in industrial countries have held overhead costs to less than 5 percent. Continuity of program funding is critical, and program design should consider sources for future funding, including:

- Cofinancing from the research provider (a grantee) to increase overall funding and demonstrate commitment to projects being financed.
- Phasing in government funding for the CRGP, with donor financing gradually declining as a percentage of total program funding.
- Building the CRGP into existing research funding so that competitive funding is used to complement the core research program.
- Establishing an agricultural research fund to support the CRGP with funding from a variety of sources, including in some cases, an endowment.
- Creating mechanisms for the private sector (farmers’ organizations, NGOs, and agribusiness) to finance grants in areas of special interest to the financier.

Lessons Learned

Programs must maintain operational efficiency, vitality, and transparency throughout implementation, with strict standards for accepting and evaluating proposals.

Proposal preparation. Competitive grants are being introduced where there is no history of competitive funding, where there are poor incentive systems in research organizations, and where producers—especially smallholders—are not well organized to express their demands. Proactive support for applicants to develop proposals helps ensure good quality proposals by investing at the outset in building capacity for on-farm diagnosis, problem
definition, socioeconomic evaluation, and writing proposals. Alternatives for building capacity may include workshops, field exercises, and the establishment of local networks with farmer organizations and extension. “Affirmative action” might be needed to strengthen the capacity of poorer regions or weaker institutions to enable them to compete for grants.

**Governance and management structure.** A sound governance and management structure is critical to the efficient operation and integrity of a CRGP (table 2.4). Pluralistic governance typically requires an umbrella council, board, or steering committee with strong private and nongovernmental participation. A program secretariat with financial management powers and an appropriate level of technical expertise is necessary for efficient day-to-day program operations.

**Table 2.4 Typical governance structure for a CRGP**

<table>
<thead>
<tr>
<th>Role</th>
<th>Description</th>
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<tbody>
<tr>
<td>Governing board</td>
<td>Responsible for overall policy for program; oversees operations; establishes program priorities and policies; represents program with funding agencies.</td>
</tr>
<tr>
<td>Technical advisory committee</td>
<td>Responsible for technical oversight of operations; provides technical input to preparation of calls for proposals; advises on peer reviewer selection; monitors technical quality of research projects. This committee is sometimes a subcommittee of the governing board or is combined with the technical review panel described below.</td>
</tr>
<tr>
<td>Secretariat</td>
<td>Responsible for managing the program and daily operations; provides support for governing and technical bodies; facilitates communications regarding program operations.</td>
</tr>
<tr>
<td>Technical review panel</td>
<td>Responsible for evaluation, scoring, and ranking proposals and making recommendations for funding.</td>
</tr>
</tbody>
</table>

Source: Authors

**Decentralization.** Basic and strategic research usually require competition and selection at the national or international level, whereas adaptive research CRGPs might be managed entirely at the state or district level. Decentralized management is especially useful in developing regional capabilities for adaptive research and developing linkages with producers. Decentralized CRGPs often benefit from oversight by a national secretariat.

**Client participation.** Farmer participation at all levels is desirable and is probably best sustained through participation in project preparation and execution, rather than in governing and review bodies. Rural producer organizations should be encouraged to collaborate in or to lead adaptive research projects under competitive grant programs. Rural women need to be represented fully in such organizations.

**Institutional reform and capacity building.** Competitive funding can be an important tool in the reform process, gradually changing the mentality of tradition-bound research organizations. In Eastern Europe and Central Asia, CRGPs have worked around entrenched institutional structures resistant to change, financing critically needed research and demonstrating mechanisms that better link research to clients.
Phased growth. Programs should start small and build on experience as scientists and administrators become familiar with program operations and until the program’s reputation and credibility have been established. New programs require a learning period as scientists come to understand and accept the proposal-writing process, and as the funding body gains experience with proposal solicitation and review.

**Recommendations for Practitioners**

Care in each step of program implementation is essential for efficient and effective CRGP operations and related investments (box 2.9). In all programs, transparency and good communication with the scientific community will enhance the efficiency and quality of research. Sound programs require:

- **Clear program objectives** that are established from the outset to determine the size, structure, duration, and type of grants to be made—whether for bringing new institutions into the research system, building institutional capacity, promoting partnerships, enhancing the quality of research, developing linkages to clients, resolving a high-priority problem, or increasing the total level of research funding.
- **Specific priorities** for funding that conform to national research strategies and objectives, so as to avoid a highly dispersed portfolio.
- **Eligibility and screening criteria** for proposals and grant recipients, as these provide the basis for proposal review and ensure quality proposals. Criteria generally cover: scientific quality, clarity of work plan, timeliness of completion, relevance to priorities, experience of proposer, adequacy of institutional support, adequacy of budget, and compliance with cofinancing arrangements. Review sheets with scoring and ranking systems provide a transparent basis for selection decisions.
- **Calls for proposals** to provide comprehensive information on program objectives and priorities and clear, detailed guidance for submitting proposals. Eligibility requirements should be as flexible as possible to enhance the participation of nontraditional research suppliers. Calls for proposals should be advertised widely to ensure that all eligible candidates are aware of the program.
- **Technical review** of all eligible proposals to evaluate each proposal according to the criteria established. High standards of review from the beginning of a program contribute to quality projects in the long term. **Technical advisory panel** members should have clear terms of reference and be selected for their scientific expertise.
- **Formal award of grants** generally made by the governing board based on recommendations from technical review panels, possibly with consideration of additional criteria, such as regional equity, strategic partnership development, and funding mobilization.
- **Monitoring and evaluation** based on detailed targets and milestones provided in project proposals and on semiannual and annual reports from grant recipients.

<table>
<thead>
<tr>
<th>Box 2.9 Potential investments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Capacity building for research organizations.</td>
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<tr>
<td>• Analytical studies for program priority setting.</td>
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<tr>
<td>• Administrative secretariat with adequate technical assistance.</td>
</tr>
<tr>
<td>• Program promotion and assistance in preparing research proposals.</td>
</tr>
<tr>
<td>• Funds for research grants.</td>
</tr>
<tr>
<td>• Monitoring and evaluation systems and impact studies.</td>
</tr>
</tbody>
</table>

Source: Authors
Program evaluations must be planned when the program is launched, and they should focus on project outputs, outcomes, and impacts. The monitoring and evaluation system must cover individual grant projects, portfolio management by the CRGP secretariat, and institutional, economic, and social impacts of the CRGP.

Selected Readings

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.

AKIS Thematic Team. 1999. “Competitive Research Grant Programs: Good Practice for Design and Management.” World Bank, Washington, DC.*


Reference Cited


This investment note was prepared by Derek Byerlee and Gary Alex, based on the Good Practice Note “Competitive Research Grant Programs Good Practice for Design and Management,” with inputs from the Sustainable Agriculture (SASKI) Thematic Team of the World Bank.
Strengthening Public Research Institutes

In many countries, institutional reforms are essential to make public research organizations more effective and efficient. A frequent—and often sound—strategy for reform involves providing public agricultural research organizations with an independent legal status and mixed public-private system of governance. This strategy can provide operational flexibility essential for sound management of research, diversification of funding, and recruitment of productive scientists. The success of these reforms depends on freedom from political interference, a clear vision and strategy, respected leadership, a stable funding base, and close links to stakeholders.

Public agricultural research systems provide a basis for the innovation and increased productivity that are necessary for a sustainable and competitive agricultural sector. National research systems are becoming increasingly pluralistic, with a growing role for the private sector, new mechanisms for research funding, and more global scientific linkages. Despite these changes, public sector NAROs continue to have a central role to undertake basic and long-term research, to provide public good products, and to support overall development of the research system. However, many public research organizations need to resolve problems of low productivity and relevance if they are to perform these roles effectively.

Autonomous National Agricultural Research Organizations

Most public research organizations were established in the 1950s and 1960s as research departments under ministries of agriculture. They grew over time with strong donor support, but they soon ran into problems because of incompatibility between civil service rules and the requirements for efficient research execution. By the 1980s, these problems led many such organizations to seek greater autonomy and sufficient flexibility to efficiently manage financial, physical, and human resources for agricultural research. Autonomy was expected to allow the research institute to get rid of excess staff and improve management systems and personnel policies. Three major types of NAROs have evolved:

- **Semiautonomous organizations** have a legal status different from the regular civil service but lack a legal corporate identity. Such organizations provide some flexibility in financial and personnel management, but often they continue to follow civil service rules. Their power to set their own business rules is often ambiguous, and they lack adequate flexibility to carry out modern scientific research. Most NAROs fall into this category.

- **Publicly owned corporations** have a mixed, public-private governing body that, in principle, has the power to set the rules for financial, personnel, and asset management. Because such organizations remain in the public sector, however, their flexibility is often constrained by political factors, and public funding continues to dominate. Research organizations in Colombia, Uruguay, and Brazil are in this category.
Private or nongovernmental research corporations are fully private, for-profit or nonprofit entities. These organizations have full powers and more independence from political processes, though they might still receive considerable financial support from government. The Crown Research Institutes in New Zealand (private, for-profit) and some research foundations such as FUNDAGRO in Ecuador (private, nonprofit) are examples.

In practice, newly created autonomous or semiautonomous research organizations have generally found themselves still reliant on public funding and substantially under the control of the ministry of agriculture. Autonomy has not solved all problems, but it has generally proven preferable to managing research programs within a government bureaucracy (box 2.10). Whatever their legal base (public or private), national or subnational organizations will likely remain the backbone of national research systems and continue to rely on public funding (Eicher 1999). Long-term development of these organizations must be planned in the context of the overall national research system, and with a view to the roles that the research organization will play in that larger system.

Box 2.10 Uruguay: effective reform

During the 1980s, it became apparent that the Uruguayan Agricultural Research Center under the Ministry of Agriculture was constrained by civil service regulations and poor linkages to farmers. As a result, in 1989, the National Agricultural Research Institute was created as a publicly owned legal entity but with full powers to set its own business rules along private sector lines. The institute is governed by a Board of Directors, with two members from government and two from farmer organizations. Farmers contribute about 40 percent of its budget through a levy (0.4 percent) on the sale of agricultural products. The government is obliged by law to provide a matching contribution.

Total research funding has increased, and the institute has developed a good reputation for its research. One key to success was strong links to clients through decentralized research stations with regional advisory councils of farmers. Commodity working groups, roundtable consultations, and a technology diffusion unit further strengthen relations with clients.

Source: Allegri 2002

Benefits

Major reasons for creating legally independent NAROs include administrative flexibility and increased stakeholder involvement.

Administrative flexibility enables NAROs to obtain competent management, maintain a creative environment, and have dependable operating budgets. Good research depends on respected leaders and highly qualified scientists, who are motivated to perform through a flexible recruitment and promotion system, the ability to reward outstanding performance and dismiss unproductive scientists, and a collegial, nonhierarchical, and nonbureaucratic institutional environment.

Increased political status of an autonomous organization can give the director the same political status as the most senior government official in the sector, can increase the
influence of the research establishment in national policy debates, and can be an asset in negotiating agreements with local or international organizations.

*Increasing stakeholder involvement* brings farmers and their associations, the broader scientific community, and other branches of government into the governance and financing of the research organization (box 2.11). This involvement helps to focus research on the most critical problems facing agriculture, informs users of new technologies being developed, and diversifies the base of funding for research. Participation by the broader scientific community, especially by universities, facilitates research collaboration and enhances scientific rigor in evaluating research programs.

**Box 2.11 Côte d'Ivoire: private National Agricultural Research Center**

By the early 1990s, poor human and financial management, weak staff accountability, and farmers’ lack of input into program content had caused the Côte d'Ivoire public research institute to become inefficient. Agricultural research came under strong pressure to provide technical support to producer organizations (POs) and extension staff. As a result, the National Agricultural Research Center was established as a private company with minority financial participation by the state. Board members are elected by the general assembly, which has a majority of users. After an external selection process, researchers were appointed and given three years to choose between remaining as civil servants with the Ministry of Sciences or becoming Center staff with private status. The researchers agreed to take Center employee status, provided their retirement and health insurance rights were guaranteed.

The Center’s structural reforms and decentralization facilitate relationships with the private sector. Researchers enjoy anew salary and incentives system, and POs, which have strong representation on the board, support the new structure. Following four years of discussion, POs, the Center, the extension agency, the Ministry of Agriculture, and donors are setting up a National Decentralized Interprofessional Fund for Agricultural Services Financing, which will finance research, extension, training, and PO development. The Fund will be managed by users, with funding from levies on major crops to ensure financial sustainability for core agricultural services. The government and donors may provide additional funding.

Source: World Bank internal documents

**Policy and Implementation Issues**

Many initiatives to create autonomous NAROs in the 1980s and 1990s failed for numerous reasons, including: fear by government officials that the organization might abuse its autonomy; institutional cultures that were too weak to prevent NARO officials from abusing flexibility; defective design (such as statutes that poorly defined roles for the governing body); flawed implementation (such as government interference with NARO management); and external and internal resistance (such as opposition from staff who feared loss of job security). Overcoming such opposition and establishing new operating procedures requires time and consistent support for management improvements.

*Decentralization* reforms are being pursued in many countries with a view to improving public services. For research systems, especially in larger countries, these reforms can serve to provide administrative flexibility, facilitate closer links to clients, and permit a
closer focus on problems of a particular province or agroecological zone. Both decentralization and deconcentration can realize some of these outcomes, but they may sacrifice economies of scale and scope and deplete the critical mass of scientists and facilities that is often necessary for productive research. Still, decentralizing adaptive research is important in almost all cases as a means of improving responsiveness to client needs.

*Salary scales* for scientists are a recurring problem in public research organizations. Although good scientists generally compete on international or regional markets, many NAROs maintain civil service salary scales for research scientists, which are inadequate. While this practice is indefensible, there is no easy solution without broader civil service reform, as senior civil servants generally resist increasing salaries for scientists above those of other government officials. Ongoing reforms in China employ a rigorous review process to identify scientists who are internationally competitive (about one-third of the total), who will be put on a special pay status that will quadruple their salaries; other scientists will be assigned to privatized research organizations or retired. Other incentive options include providing opportunities for consulting or contract research, liberal training and sabbatical policies, and arrangements to commercialize research innovations.

**Lessons Learned**

There is no single "right way" to reform research organizations, as the specific country context and maturity of the existing research organization must be considered.

*Key reforms.* To be truly independent, NAROs must have an independent governing body to prevent undue political interference. A governing body representative of major stakeholders, selected on the basis of professional merit, should have freedom to select the chief executive officer based on merit and to establish policies for open, transparent, merit-based recruitment and promotion and performance-based evaluation and reward systems. The chair of the governing body should generally be a highly respected individual from outside government.

*Separation of funding and execution.* Increasingly, the bodies that fund research are separate from those that perform research. Competitive and contractual funding mechanisms favor organizations that can deliver high-quality, relevant research (box 2.12). They need to compete for grants, and the signing of results-oriented contracts often improves performance.

**Box 2.12 Bangladesh: failed reform**

The Bangladesh Agricultural Research Management project (1996-2001) failed to achieve projected efficiencies through institutional reform of the structure and role of the Bangladesh Agricultural Research Council and associated national agricultural research organizations (NAROs). Despite having financed useful research, the project outcome was considered "moderately unsatisfactory" and sustainability "unlikely."

Problems started early. Although the government passed an act to empower the Council, there were requests for "flexibility" in the reform agenda even before appraisal. At appraisal, the government announced that personnel reforms were not possible, and research institutes could not
be separated from parent ministries. During implementation, three major problems were not addressed—lack of Council authority over research institutes, lack of central budget and program coordination, and excess numbers of institutes and stations. Fundamental problems included the lack of a high-level champion for reforms and the inability to subordinate individual interests of ministries and institutes to the need to improve overall coordination and efficiency. As a result, research efficiency suffered, and the Council is considered “unsustainable.”

Source: World Bank internal documents

Broader public sector reform. Many countries are attempting to modernize and reorganize the public sector as a whole. In reforming research organizations, consultations with those managing broad public sector reforms are important.

Operating rules. In creating or reforming an autonomous research body, considerable time and resources are required to develop appropriate rules and policies. A governing body and a chief executive officer with requisite skills and experience from outside the public sector facilitate this process. Those with only public sector experience are likely to copy government business rules and policies, defeating major objectives of autonomy. Particular attention should be paid to developing human resource management and incentive systems.

**Recommendations for Practitioners**

Past experience provides a number of good practices for successful NARO reform and related investments (box 2.13).

- A thorough analysis of current performance is required to lay the foundation for clear mission and vision statements that establish a clear role for the organization, define public sector roles, and link the organization to funding sources, technology transfer agencies, and national policy organizations (box 2.14).
- Planning should be fully participatory through workshops and consultations that include a full cross-section of farmer categories.
- Identifying a leader or “change” manager” is important, because independent research organizations with poor leadership often fail.
- An effective governing body that is highly professional, representative of key stakeholders, and independent is critical. Terms of reference for the governing body should clearly define its role in formulating policies and priorities for the organization.

**Box 2.13 Potential investments**

- A management change team.
- Technical and legal assistance for developing the legal documentation for establishment.
- Technical assistance and training for establishing operating procedures, manuals, and guidelines.
- Civil works and equipment.
- Training for governing board members, national agricultural research organization management staff, and key stakeholders.
- Core operational funding for research programs and for capacity development on a declining basis.
- Funding for competitive grants programs.
- Technical assistance in developing diversified sources of funding.
- Partnerships and linkages with international research programs.

Source: Authors
but avoid interference in its day-to-day management.

- Institutional and legal reform should be accompanied by strategies to diversify funding, usually through participation in competitive grants schemes, commercialization of research products, tapping of private funding through production levies, contracts with the private sector, and joint ventures.
- The price of flexibility is greater accountability for results. Funding agencies must establish realistic, clearly understood performance measures of evaluating performance. Staff of funding agencies need training in this area.

### Box 2.14 Stakeholders to include in the governing body

- Producer organizations.
- Agribusiness sector.
- Ministries of agriculture, science and technology, and finance.
- Technology transfer agencies—public or private—including NGOs.
- Distinguished university scientists.

Source: Authors

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### Selected Readings

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.


### References Cited


This investment note was prepared by Derek Byerlee and Gary Alex, based on the Good Practice Note “Reforming Agricultural Research Organizations Creating Autonomous Bodies and Managing Change,” with input from the Sustainable Agriculture (SASKI) Thematic Team of the World Bank.
Enhancing University Participation in National Agricultural Research Systems

Universities, with their functions of educating students and generating and disseminating knowledge, are central to productive AKISs. The number of agricultural faculties has grown rapidly, and because about half of the agricultural scientists in developing countries work in universities, they have considerable potential to carry out research. University faculties devote about 25 percent of their time to research, and the balance to teaching programs, supervising postgraduate students, and consulting. Agricultural universities and faculties of agriculture in universities face multiple challenges: providing relevant and high quality training for future agricultural scientists, mobilizing funding for research, disseminating research findings, and recruiting, promoting, and retaining gifted teachers and researchers.

Agricultural universities and faculties of agriculture in developing countries are central to building a comprehensive AKIS. They train future research staff and have the potential to use existing staff and facilities, such as libraries, laboratories, and demonstration farms, to carry out research at marginal additional cost. Many universities also provide consulting services to various public, private, and nongovernmental organizations.

Degree training is the primary function of agricultural universities. From the early 1960s to the mid-1980s, agricultural universities helped to quadruple the number of developing country agricultural researchers, yet results from the early phase of donor investment in university research have been mixed. Some agricultural universities actively participate in AKIS and generate high-quality research, but others have seen their research capacity erode. Although many universities have expanded training capacities, they have been unsuccessful in achieving fiscal sustainability and establishing sound research programs. This situation is changing as CRGPs have increased university participation in agricultural research of national importance in a number of countries, including Ecuador, Brazil, and Chile.

International donors have invested heavily in universities and faculties of agriculture. From 1964 to 1990, World Bank-financed projects provided US$713 million for 41 projects supporting universities (both agricultural and general) in 25 countries. From the 1950s to 1996, the United States Agency for International Development (USAID) provided US$456 million for 63 agricultural universities in 40 countries. In the 1990s, donor support to universities declined sharply, but there has been a renewed interest in the important symbiotic relationships between investments in agricultural higher education, research, and extension. Three recent examples illustrate the “new directions” in donor strategies for supporting higher (tertiary) education:
The World Bank publication *Constructing Knowledge Societies* (2002) stresses the powerful role that universities play in creating and disseminating knowledge, building professional capacity, and reducing poverty.

- Four U.S. foundations committed US$100 million to assist in reforming universities in six countries in Africa over 2000-2005.
- In 2002 USAID launched a new global training and capacity-building initiative to increase graduate training in food and agriculture in U.S. universities and to strengthen agricultural higher education in developing countries.

**Box 2.15 Uruguay: linking universities to the National Research Institute**

In Uruguay, effective linkages have established a research partnership between universities and the National Research Institute.

- Ten percent of the Institute’s research budget is set aside for competitive contracting for research with outside agencies. Universities receive almost half of this funding.
- University and Institute staff meet annually to prepare joint research programs.
- Senior Institute staff spend up to 20 percent of their time teaching at universities.
- The Institute facilitates university linkages with international programs (especially the international agricultural research centers).
- University students receive National Agricultural Research Institute fellowships.

Source: Hobbs et al. 1998

**University Contribution to National Agricultural Research Systems**

Many universities have the potential to participate in national agricultural research systems (box 2.15). Competitive grants, contracts, and other mechanisms provide the necessary links to do this (box 2.16). In addition, as private universities are becoming more important in the provision of higher education, they also should have an equal opportunity to compete for government support for technology development programs.

**Box 2.16 Ghana: establishing a university role in national agricultural research programs**

In Ghana, the Bank-supported National Agricultural Research Project, initiated in 1992, helped bring universities into the national research program through two mechanisms:

- The Ghanaian National Commodity/Factor Research Programs, established for 17 strategically important research areas, are led by Program Coordination Committees. Scientists from universities serve on these committees and may serve as program coordinators.
- A research grants scheme was designed to draw universities and other institutions into the research system and to complement research activities under the national program. The scheme gave priority to basic and strategic research. By mid-1998, it had funded 110 research projects, including 34 that supported postgraduate research at local universities.

Source: World Bank internal documents

The complementary nature of research, education, and extension points to the need for close communication and cooperation among these core institutions in pluralistic national technology development systems. Agricultural universities and agricultural faculties can make the following contributions:
• **National research.** A university can assume full responsibility for public sector agricultural research by establishing a NARI within the university.

• **Basic research.** A university can focus on basic and strategic research, leaving applied and adaptive research to other institutions.

• **Regional research.** A university can assume lead responsibility for work on a particular commodity or production system within its region.

• **Consultant services.** A university can provide consultant services by providing its research findings to NARIs, NGOs, international agencies, and commercial firms.

**Policy and Implementation Issues**

Universities must adapt to a changing global agricultural environment and address new training and research challenges related to NRM, agribusiness, biotechnology, and trade.

*Training future research specialists.* Historical support of donor-funded overseas postgraduate training is declining. World Bank support for such training declined by 34 percent from 1990 to 1997, and the number of USAID-financed postgraduate students studying agriculture in the USA fell from 310 in 1990 to 82 in 2000.

Long-term training for most master’s degree students is now undertaken in developing countries, and doctoral students are educated in both industrial and developing countries. The next challenge is to improve the quality and fiscal sustainability of universities that have developed a regional reputation for high-quality master’s and doctoral training.

*University research and national strategies.* Research priorities must balance the university’s independence against strategic national research needs, with policies and strategies designed to encourage, not stifle, individual initiative by scientists. Tying national funding to research on high-priority topics will stimulate research in these areas.

*Faculty incentives.* University programs require adequate salaries, innovative policies relating to faculty consulting, and incentives to faculty for development-oriented research and for mentoring and supervising postgraduate students. When university scientists take second jobs or consulting work to supplement their university salaries, research programs are often disrupted and the time available for research and supervision of postgraduate students is curtailed.

*Financing university research.* Competitive funding mechanisms are becoming increasingly important for financing university research (box 2.17), but if overhead costs are not covered, there can be a net loss of funds available for the university’s own research program. A sustainable agricultural research program requires funding for:

• Infrastructure (building laboratories, establishing electronic communications, procuring equipment, and acquiring land or other facilities) and training research students to the master’s and doctoral degree level.
• Thesis research of postgraduate students, possibly funded through a competitive grant program or a research fund dedicated to thesis research.

• Strategic research programs focusing on particular problems, such as issues in biotechnology or natural resources management. These programs require long-term funding and are usually inappropriate for funding through a competitive system.

• Maintaining relevance and effectiveness of research programs by establishing mechanisms to expand interaction with farmers. Universities can gain local agricultural knowledge by recruiting students from farm backgrounds, integrating students into joint university-NARI research projects, and expanding research in the rural social sciences and in rural production systems covering farming systems, ecosystems, and agroecological regions.

Lessons Learned

Universities can conduct high-quality research, provided they have an adequate policy framework, strategic plans, institutional structures for research, and project investments (box 2.18).

CRGPs targeting university scientists are cost-effective mechanisms for linking university research capability to national programs. Assistance with grant proposal preparation might be needed to help universities compete for such funding.

The development of research infrastructure should conform to university research priorities, with expansion limited to essential facilities that can be maintained over time. Investments should include human

Box 2.17 Chile: financing university research

In Chile, even though the primary mission of higher education is training, the budget for agricultural research at the nation’s 17 universities reached US$4 million in 1995. Funding came from:

• Government grants to universities, including a research fund used to contract staff.
• National competitive research grant programs (CRGPs), which are a major source of research funding but provide funding that is unstable, unfocused, and does not cover overhead costs.
• Government research contracts, mostly for applied and adaptive research projects.
• Sale of research goods and services, especially contract research.
• Research grants from private sector and international sources.
• University income and other sources that provided small amounts of research funding.

Source: Venezian 1993

Box 2.18 Uganda: building an integrated agricultural knowledge and information systems

In Uganda, the five-year Agricultural Research and Training Project, initiated in 1993, built an integrated system for agricultural research and education that includes universities. Support to the university system covered:

• Training to fill critical gaps in the university faculty.
• A Continuing Agricultural Education Center to provide demand-driven training for clients.
• A program for twinning Makerere University with foreign universities to strengthen curricula.
• Capacity building for diploma-level training at agricultural colleges.
• Close coordination with universities in developing an effective national agricultural research institute (NARI).

Source: World Bank internal documents
resource development through postgraduate training and sabbaticals as well as investment in equipment, buildings, and related facilities.

Postgraduate programs provide universities with a cadre of motivated and low-cost student researchers. Client-oriented postgraduate research contributes to the relevance of university programs, links research to teaching, and has the potential to attract funds from the private sector, donor projects, and other sources. Successful postgraduate programs require an experienced faculty, an adequate physical infrastructure, library and Internet resources, and modest operating budgets.

University programs establishing strategic research alliances with other institutions can strengthen national research programs while building postgraduate training capacities in universities. Ecuador’s competitive grants program financed strategic alliance grants, which enabled universities to establish partnerships with local and foreign institutions for developing postgraduate training programs and expanding core research capability.4

**Recommendations for Practitioners**

Balanced development of efficient and sustainable technology systems suggests that universities must become important contributors to pluralistic national technology systems. Project investments (box 2.19) can:

<table>
<thead>
<tr>
<th>Box 2.19 Key investments to develop university research capacities include:</th>
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<tr>
<td>• Infrastructure (human and physical).</td>
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<td>• Postgraduate degree training.</td>
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<td>• Strategic alliances.</td>
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<td>• Core research support.</td>
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<td>• Competitive research grants.</td>
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*Evaluate university capacity to contribute to R&D.* Assessments of institutions and their agricultural research capacities and programs should help to categorize universities as (1) deserving broad program support and capable of effectively absorbing such support; (2) needing reform but still appropriate for targeted assistance; or (3) requiring major reforms before investments can be justified. Major university investments should also be conditional on commitments to respond to market and client needs.

*Establish mandates and structures.* At both the national government and university levels, improving the framework for productive university involvement in research generally requires:

- Providing legitimacy and visibility to university research programs, helping align programs with national priorities, and enabling them to attract government funding.
- Providing support for universities to conduct research effectively. This effort often requires a policy statement; a strategy outlining priorities and links to users and other programs; incentive systems that reward mentoring and supervision of postgraduate

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4 See the IAP, “Ecuador: Strategic International Alliances for Capacity Building and Research.”
students and client-oriented collaborative research; and a small research management unit to facilitate funding, execution, planning, monitoring, and evaluation.

- Forming NARI-university partnerships, which include joint research projects, joint supervision of postgraduate students, and joint seminars and annual research reviews.
- Linking with clients and stakeholders to ensure that university programs respond to client needs. Links can be established with POs and rural NGOs that promote equity in development.
- Encouraging research publishing to disseminate and promote research findings and increase the visibility of university programs. Equal incentives should be provided for local publication of development-oriented research and international publication of more academic work.

Selected Readings

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.


References Cited


This investment note was prepared by Carl Eicher and Gary Alex, based on the World Bank Good Practice Note, “Integrating Universities into National Agricultural Research and Extension Systems,” with input from the Sustainable Agriculture (SASKI) Thematic Team of the World Bank.
Local Agricultural Research Committees

Local Agricultural Research Committees (known by their Spanish acronym, CIALs) are locally elected groups of farmers who run volunteer agricultural technology testing services financed by local contributions in cash and kind and supplemented by state or NGO funds. CIALs enable farmers to express their technology demands and participate in designing, testing, and disseminating appropriate technologies. This adaptive research service is accountable to its clients, increases the outreach of technology services to remote areas, and provides feedback to improve technology design. Training facilitators and committees is a one-off investment that enables a research and extension program to expand its coverage at low cost or to reduce the overall cost of maintaining contact with farmer groups. The CIAL approach has been adapted successfully in eight Latin American countries and is expanding in Africa and Asia.

Development of technology recommendations is costly and time consuming, and mechanisms to ensure feedback to research and extension (R&E) providers from poor farmers are essential but widely lacking. The consequence is the low rate of technology adoption by resource-poor producers. Even where a market for R&E services exists, the weak capacity of farmers to express demand is a constraint. However, resource-poor farmers in tropical countries have successfully developed profitable and ecologically sustainable agricultural technologies on their own. Collaboration between farmers and researchers at an early stage in the design and testing of technologies has the potential to blend local and nonlocal technical knowledge and lead to successful innovations.

Local Agricultural Research Committees

Strengthening the capacity of poor farmers to articulate their research needs and to participate in the design, testing, and dissemination of appropriate technologies is the objective of widespread experimentation with farmer participatory research groups in developing countries. CIALs were developed to provide farmers and POs with a research service that is accountable to its client group, increases the ability of R&E services to reach remote areas, and provides feedback to improve the design of technology.

A CIAL is a farmer-run, volunteer research service that is initiated by and answerable to its client group. Client groups may be informal or formally organized groups of farmers motivated to test agricultural innovations (including the best local practices) when appropriate technologies are lacking or unproven for local conditions. The client group elects a committee of farmers chosen for their interest in experimentation and willingness to serve. The client group can replace committee members who do not put in enough time and elect new ones. Committees, ranging in size from 4 to more than 20 members, conduct research on local, priority topics. This approach enables farmers to share risk and build on local experience when trying out untested agricultural innovations.

The committee works with its clients to establish priorities for research topics, consults with R&E providers, raises funds, plans experiments, conducts trials on several farms, and regularly reports results to clients and R&E providers. Initially, the committee organizes a diagnostic process in which all clients participate in consultations with other
farmers. When priorities are being established, attention to gender or ethnic differences is important, and special interest groups may need or demand a committee of their own. A local or regional facilitator encourages client groups to choose a research theme with good chances of success and with the potential to benefit most of its clients.

When the client group identifies a research topic, the committee searches for information to establish whether there is really a need for research. If the committee finds that locally-proven technologies are available, it asks farmers or R&E providers experienced with the technology to provide communitywide training. If committee members are not sure about what works locally, the experiment will generally compare multiple, unproven solutions that may be indigenous or of external origin.

The major costs of establishing a CIAL are incurred during the first year for training and a one-off petty cash or inputs fund for operations. For example, in Colombia, facilitator training by salaried professionals costs approximately US$600, and the start-up funds for CIAL operations (the CIAL Fund) range from US$25 to $500 per CIAL in cash or kind. The facilitator, who may be a professional or a farmer with prior experience in a local committee, assists client groups to establish CIALs and then progressively hands over responsibility to the committee. One facilitator can support 50 or more CIALs, provided that person can bring some members to regular meetings or has transportation to visit them. Training of facilitators and committees is a one-off investment that enables a research and extension program to expand coverage at a low cost. Training of experienced farmers as facilitators dramatically reduces costs.

The CIAL process has been adapted successfully to different situations, provided that committees, facilitators, and client groups keep to the basic principles outlined in the Recommendations for Practitioners section. Adaptations by NGOs, universities, local governments, producer organizations, vocational schools, and experiment stations have resulted in a wide variety of committees (box 2.20). The main difference in committee adaptation depends on whether the committee’s priority is research or community development. If it is research, a small group of expert farmers experiment with innovations on behalf of their client group. If the priority is community development, the CIAL process may be included in social projects, such as credit schemes.

All CIAL approaches require effective links to research organizations. When farmers are very poor and there is a high level of cultural dependency or risk avoidance, adaptations as outlined in box 2.21 are useful first steps in establishing effective CIALs.

Box 2.20 CIAL development and spread

The CIAL approach to participatory on-farm research was first used by the International Center for Tropical Agriculture (CIAT) in 1992. By 2003 over 250 CIALs operated in eight Latin American countries. An unknown number of adaptations of the approach exist in East and West Africa and Asia, including China.

Source: ISNAR

Box 2.21 Alternative approaches used in different situations

- Where short-term food security is a priority, begin by evaluating treatments in researchers’ trials and subsequently share risk in farmer-run experimentation (Ecuador, East Africa).
• Run a collective production plot using proven technologies together with the Local Agricultural Research Committee’s (CIAL’s) small experimental plots for untried technologies. The collective production helps compensate committee members for their time and adds to the petty cash fund (Honduras, Colombia).
• Test and monitor innovations on farms without establishing formal experiments. This is especially useful with livestock or natural resource management (NRM) practices (East Africa, Southeast Asia).
• Elect a large committee. In Northeast Brazil large committees sustained CIALs through periods of seasonal migration. In Honduras, large committees made the human capital development benefits of membership accessible to a broader cross-section of the client group.
• Create a petty cash fund by providing the CIAL with experimental inputs in kind and then using profits from trials to fund the committee’s activities. This approach enabled CIALs in Bolivia and Colombia to increase their petty cash funds.
• Run the petty cash fund as a revolving credit fund or as a small venture capital fund that makes loans for equipment that is rented out to the client group.
• Form a CIAL to provide R&D on new products or processes for small agroenterprises.

Source: Authors

Benefits

CIALs have achieved three types of benefits: more rapid technology adoption, human and social capital formation, and welfare benefits. Technology adoption and welfare benefits accrue to the wider client group; human and social capital formation benefits accrue mainly though not exclusively to the members of committees. Farmers and their organizations gain new knowledge and skills plus the capacity to engage R&E providers in support of local experimentation (box 2.22).

Box 2.22 The potential impact of Local Agricultural Research Committees

• Strengthened farmer experimentation. An impact study of over 300 households in Colombia found that individual farmers influenced by Local Agricultural Research Committees (CIALs) were involved in over 50 different kinds of experiments on their own.
• Improved the quality and relevance of on-farm research. Monitoring shows that 75 percent of CIAL experimental data can be statistically analyzed by scientists and that other data are meaningful to farmers (CIAT 1998).
• Developed agroenterprises. CIALs have introduced profitable new crops, postharvest processes, and/or new varieties.
• Improved food security. An impact study in Colombia found that communities with CIALs had fewer respondents who experienced food shortages in the “hungry months,” compared to those without.
• Increased poor people’s access to new technologies. In Colombia, analysis of 15 technologies found that 63 percent of farmers in the poorest strata were adopting between 6 and 15 CIAL technologies, and they were as likely to do so as the better-off strata of farmers. New technologies were adopted faster in communities with CIALs and their neighboring communities than in other communities that relied on traditional research and extension.

Source: Authors
Policy and Implementation Issues

Financial sustainability. CIAL costs depend primarily on the frequency of visits by facilitators and the number of CIALs supported by each facilitator, which depend in turn on the density of CIALs in a region. Typical levels of facilitator-CIAL contact are biweekly for a new CIAL. After the first experimental cycle, the frequency of contact is reduced progressively, and costs typically drop by 50 percent. In Colombia in 1999, the cost of establishing a CIAL averaged US$670 for the first year, declining to US$400 in the second year and US$200 in the fourth year. The costs of CIAL operations are often partly financed by sponsors who provide experimental inputs and/or petty cash (for example, NGOs, local governments, R&E providers), and they will be partially or wholly financed by local farmers’ contributions and community-based fundraising by committees (for example, raffles, dances, collective production plots). Once a petty cash fund has been established, most committees keep their fund going, and some have increased their funds over time. The costs of facilitator salaries and training are most commonly borne by sponsors such as NGOs, universities, local governments, or public sector R&E providers.

Lessons Learned

Institutional support. CIALs provide a local adaptive research service that accelerates innovation when an active relationship is maintained with an NGO or state research or extension provider. Mature CIALs can function successfully with as little as three or four contacts per year with their facilitator, but geographically isolated CIALs do not realize their full research potential. R&D providers working with CIALs must commit to regular contact, respect for farmer research, punctuality, accountability, and shared decision making. Support from R&D decision makers and links to local government enhance sustainability (box 2.23). In the initial phases, institutions can overburden CIAL members with incessant demands for meetings, but continuing contacts can motivate participation.

Organizational base. CIALs work best when formed inside a client group’s informal or formal organization (for example, when a community, farmer association or cooperative, women’s group, parents’ association, parish council, or small enterprise elects and

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<tr>
<th>Box 2.23 Bolivia: organizing Local Agricultural Research Committees in municipalities</th>
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<td>Sustainability and accountability can be ensured by establishing channels whereby Local Agricultural Research Committees (CIALs) set priorities for their research and report back to established farmer organizations and local government. In Bolivia, municipalities are required by law to identify and respond to community demands for services, and rural municipalities must involve farmers in preparing municipal development plans and in local boards for economic promotion that coordinate development efforts. Colmi Municipality already has 10 CIALs with committee members elected by the farmer organizations or rural syndicates, themselves elected by communities. The CIALs are linked with the municipality through their syndicate’s central office, which participates in Colmi’s local board for economic promotion and serves as a channel for CIALs to influence municipal priorities, request support, and contribute to municipal projects. This arrangement is proving to be an important source of human and social capital.</td>
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oversees the committee). Establishment of a CIAL inside an R&E organization is a second-best option, as it can result in loss of direct accountability to clients.

**Social considerations.** CIALs can catalyze commitment to collective action and to women’s participation, but factionalism, conflict, or suspicions within the client group can seriously undermine its support for a committee. Women’s participation in CIALs is often difficult and associated with the need to gain acceptance. A CIAL must regularly report on progress to its client group to ensure accountability of the committee, so that research products belong to the community, not to the committee or individuals.

**Real technology development.** CIALs are cost-effective when they build local capacity such as helping poor people collectively manage untried innovations. If clients, committees, facilitators, or R&E providers judge CIALs only on their success in teaching large numbers of farmers to adopt proven technologies, they undervalue the generation of useful knowledge made available to many by CIALs. Restricting CIALs to demonstrating technologies usually means their experimentation is not driven by the client group’s demand for innovation but by the facilitator’s perception of what is “safe.” CIALs play an important role in participatory learning by generating new information, but they are a complement to assisted learning, not a substitute. In practice, many CIALs engage in both research and assisted learning.

**Recommendations for Practitioners**

Many features of the CIAL process (such as type of sponsoring organization, who facilitates, committee size, type of experimentation, size of petty cash fund) and related investments (box 2.24) can vary greatly, provided that sponsors, trainers, client groups, committee members, and facilitators understand and adhere to the following basic principles:

- Form CIALs by motivating the client group to elect farmers interested in testing agricultural innovations and by building on local experience. Programs need to support farmers in learning how to innovate rather than demonstrating technological “fixes.”
- Establish a high-priority research topic that is relevant to the majority of farmers in the client group.
- Plan activities that regularly generate and sustain the petty cash fund needed to support CIAL operations.
- Expand and rotate committee membership, and ensure that committee members provide regular progress reports on experiments to their clients, so that that research products reach the wider community and not just the committee members or the sponsor.

**Box 2.24 Potential investments**

- Training for Local Agricultural Research Committee (CIAL) facilitators: US$600 per person for a short course, plus one year of follow-up support. One facilitator can support up to 50 mature CIALs.
- Start-up funds for CIAL experiments: a one-time, nonrenewable investment in a CIAL fund can range from US$25 to US$500 in cash or kind.
- Average running costs per CIAL in Colombia were US$670 for the first year, US$400 in the second year, and US$200 in the fourth year.

Source: Authors
• Include committee experimentation for very poor, risk-averse client groups in social projects with short-term returns to sustain commitment over time and build local capacity.
• Encourage CIALs to exchange visits and sponsor their own regional meetings to exchange results.
• Minimize costs of visiting CIALs by possibly targeting agroecological zones that can be reached from an experiment station or municipal extension office.
• Train experienced farmers with prior experience in a CIAL as facilitators to reduce costs of facilitation, especially when moving into large-scale implementation.
• Promote attendance of scientists and key R&D decision makers at CIAL meetings to ensure their support for CIALs.

Selected Readings

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.


CIAT (International Center for Tropical Agriculture). *Solutions That Cross Frontiers.*
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This investment note was prepared by Jacqueline Ashby of the International Center for Tropical Agriculture (CIAT), Cali, Colombia.
Biotechnology, Biosafety, and Agricultural Development

New techniques of biotechnology can stabilize yields and improve rural incomes, reduce negative environmental impacts, provide nutrient-enhanced and better quality food, and deliver vaccines and antibodies to improve human and animal health. While most benefits have occurred in industrial countries, the techniques have considerable potential for sustainable small-farm systems in developing countries. Yet some of these new technologies are controversial, owing to their potential environmental and health effects and socioeconomic implications. Experience so far has shown that biotechnology strategies must be country-specific, depending on needs and scientific capabilities. All countries, however, will need the capacity for developing technology policies and strategies, a strong regulatory framework, and scientific skills to make use of appropriate technologies.

Agricultural biotechnology is increasingly seen as a valuable tool for addressing production and nutritional constraints in developing countries, particularly in commodities important to poor producers and consumers. This view is supported in the World Bank’s rural strategy, Reaching the Rural Poor, which commits the Bank to helping developing countries assess and safely use new technologies. However, continuing controversy and debate over possible adverse health and environmental impacts, ethical and legal issues relating to IPRs, fears that access to certain markets will be restricted, and limited capacity and resources to comply with biosafety regulations have all slowed adoption in developing countries. To benefit from rapid global advances in the biological sciences, developing countries will have to invest public funds in products that are not of commercial interest to the private sector but are of high priority to their poor producers and consumers.

What Is Biotechnology?

“Agricultural biotechnology” encompasses a wide range of technologies and products that can improve the productivity or quality of crops, livestock, fisheries, and forests. The first-generation biotechnologies, including plant tissue culture and micropropagation techniques, molecular diagnostics of crop and livestock diseases, and embryo transfer in livestock, have already been adopted in many developing countries. They are simple to use, often inexpensive, and relatively free of regulatory requirements and public controversy.

The subsequent generation of biotechnology tools and products, based on molecular biology, is providing revolutionary advances in genetic knowledge and the capacity to change DNA. These molecular technologies can be used either as research tools to support plant and animal breeding (for example, through the use of genetic markers and gene mapping), or they can be used as a means of “precision breeding,” in which a gene conveying a specific trait (such as high vitamin A content or virus resistance) is transferred within or across species to generate transgenics (genetically modified organisms, commonly known as GMOs). These molecular approaches require advanced skills, research laboratories, and the capacity to manage intellectual property—requirements that may pose a constraint for developing countries. The transgenic crops...
developed using these techniques also require regulatory capacity to assess and manage possible environmental, health, and socioeconomic risks.

Although commercial transgenic varieties have been developed for only a small number of crops and traits, the area planted to transgenic crops has grown very rapidly since the first crop was commercialized in 1994, reaching 90 million hectares by 2005 (figure 2.5). Over 8 million farmers in 21 countries grow transgenic varieties. Of these farmers, 7.7 million are small-scale farmers in developing countries. The first 10 years of large-scale production of transgenic varieties has been dominated by the private sector, both as the developer and as the dissemination channel for the technology, with an emphasis on export crops and traits of interest to industrial countries. For the full benefits of biotechnology to reach poor farmers and consumers in developing countries, national and international public institutions will need support to build research capacity in agricultural biotechnology, complemented by the managerial skills required to negotiate access to proprietary technologies developed by other private and public research organizations. Developing country scientists need to be able to apply these innovations to national varieties of food and export crops. Some benefits can be achieved by using biotechnology to increase the accuracy and speed of conventional breeding methods, whereas others can only be achieved, or only be achieved sufficiently quickly, through the use of transgenic breeding methods.

Figure 2.5 Global area of biotech crops, 1996-2005 (million acres)

Benefits

Modern biotechnology tools have the potential to raise agricultural productivity significantly and in a more environmentally-friendly manner, supply cheaper and more
nutritious food, and contribute to poverty alleviation. Many biotechnologies offer substantial benefits, making crop and livestock production more stable and productive, primarily by improving the resilience of plants and animals exposed to diseases and pests. Examples include insect-resistant maize in East Africa, insect-resistant cotton in China (box 2.25) and India, and marker-assisted selection for tolerance to sleeping sickness in African cattle.

Input costs may also be lower as resistance or tolerance to insect pests and diseases is bred into crops and animals, reducing the need for externally applied pesticides. For example, in Mexico, pesticide use on cotton fell by more than 80 percent, from an average of nearly 14 kilograms per hectare of active ingredient in the 1980s to about 2 kilograms per hectare in 2002, after farmers started to plant a Bacillus thuringiensis (Bt) cotton variety resistant to bollworm (Traxler et al. 2003). Lower pesticide use has significant environmental and health benefits (box 2.25), and herbicide-resistant crops can be used to introduce minimum-tillage systems that reduce soil degradation and erosion. There is also potential to improve food quality—one example is “golden rice,” which has high vitamin A content—and to develop healthier animal and plant products, such as leaner meats, improved fatty acid profiles in oil crops, and fewer fungal toxins in food crops.

**Box 2.25 Reducing insecticide use and insecticide poisoning among framers in Hebei and Shandong, China**

A survey of agricultural producers in China demonstrated that adoption of Bacillus thuringiensis (Bt) cotton increased production efficiency and improved farmer health. After farmers adopted the new Bt varieties, both insecticide use and poisonings among small-scale farmers fell five-fold, from 57.8 to 10.3 kilograms per hectare and 22.2 to 4.7 percent, respectively. A survey of China’s plant biotechnologists showed that China is developing the largest plant biotechnology capacity outside of North America. The list of genetically modified plants already in the field trials, including rice, wheat, potato, and peanut varieties, is impressive and differs from those being worked on in other countries. Poor farmers in China are cultivating genetically modified plants on a greater area than small-scale farmers in any other developing country.

Source: Huang et al. 2002

**Biosafety Frameworks**

The application of genetic engineering to crop and livestock improvement is a relatively recent phenomenon. In 1994 the first transgenic variety reached the market in the USA, and as increased numbers of transgenic products were field-tested and commercialized, questions arose about their safety. As the development of molecular biotechnology is relatively recent, there is yet no model or single best approach for dealing with safety issues.

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5 See the IAP, “India: Focus on Biotechnology.”
The risks associated with GMOs in agriculture generally fall into two categories: food safety and environmental safety. Safety concerns related to genetically modified food products include possible changes in their nutritive value, allergenicity, and levels of toxins. Environmental risks include the possibility that one or more transgenes could flow into other cultivars of the same species or into related weed species, with the risk of spontaneously developing weeds that resist diseases, pests, and herbicides and could potentially upset the ecosystem balance. Another environmental risk is the possible effect on nontarget organisms from crops with resistance traits operating through insecticidal protein expression. Still another is the potential displacement of traditional cultivars by a small number of transgenic cultivars, which would reduce the biodiversity typically found in smallholders’ fields.

Biosafety frameworks are required to assess and manage such risks. They typically include five key elements: national policies; national inventory and evaluation; knowledge, skills and capacity; regulations governing risk assessment and risk management; and systems to monitor, inspect, and implement regulations (ISNAR Decision Support Toolbox for Biosafety Implementation, http://www.isnar.cgiar.org/ibs/biosafety/). Ideally the evolution of a national biosafety system begins with a national policy that is the basis for legislation and/or regulations, leading to design and implementation of the systems necessary to undertake risk analysis, inspection, monitoring, and enforcement. A national assessment of existing regulatory, scientific, technical, economic, and social capacity is relevant to the policy and implementation processes. Transparency and public participation are essential to build public trust in the institutions and risk assessment and risk management procedures that constitute a national biosafety system.

Except for a few countries with extensive or growing domestic biotechnology sectors, the development of a comprehensive national capacity for a biosafety system is not likely to be necessary or feasible. Pragmatic, cost-effective solutions to the problem of establishing regulatory systems will often involve combining responsibility for the regulatory compliance on risk assessment and risk management in one agency, which will then draw on expertise in academia and private and civil society, guided by internationally agreed norms. Experience to date has shown that effective coordination between ministries of environment, science and technology, health, agriculture, industry and trade, and commerce is essential, although it often remains a great challenge. Countries with a small science community can implement effective biosafety systems by capitalizing on external expertise and information and harmonizing risk assessment principles, information requirements, and standards of assessment on a regional basis. Harmonizing biosafety standards requires: the adoption of common values and objectives; shared interests (an important export commodity like cotton, for example, or a regional trade agreement) and concerns (for example, when countries share a center of biodiversity); the need to overcome differences and avoid disputes; the need to cooperate with other interests; and the need to simplify procedures. In the absence of some or all of these factors, the chances of effective harmonization are limited. The issue of biosafety as a global concern has been raised by the Cartagena Protocol, which sets out the rules for assessing the environmental safety of living modified organisms (LMOs) and their transboundary movement (box 2.26).
Box 2.26 The Cartagena Protocol on Biosafety

Adopted in January 2000 as a supplement to the Convention on Biological Diversity, the Cartagena Protocol on Biosafety addresses the safe transfer, handling, and use of any living modified organisms (LMOs)—seeds, roots and tubers, fish eggs, embryos, and so on—that may have an adverse effect on biodiversity, taking into account risks to human health and focusing specifically on transboundary movements. The Protocol allows governments to indicate their willingness to accept imports of agricultural commodities that include LMOs by communicating their decision to the world community via the Biosafety Clearing House (http://bch.biodiv.org/), a mechanism set up to facilitate the exchange of information on, and experience with, LMOs. The aim is to ensure that recipient countries have both the opportunity and the capacity to assess risks involving the products of modern biotechnology.


Policy and Implementation Issues

*Ecological and food safety risks.* As mentioned, possible risks from using biotechnology tools and techniques relate to environmental and food safety. The likelihood of risks and existence of appropriate risk management methods will contribute to risk assessment regulations and guidelines governing biosafety. Risk and risk management strategies are likely to be case-specific, depending on the trait, location, and management of the plants or animals in question.

*Costs and capacity.* Molecular biotechnology research can require substantial investments for the necessary biosafety framework and laboratories, for training scientists (who must remain current in this rapidly changing field), and for research operating costs. Consequently, a firm commitment that ensures sustainable financing is needed before investing in biotechnology.

*Intellectual property.* Access by developing countries and especially poor people to new technologies protected by patents (largely held by private companies, the major developers of new technology), is an area of controversy. Developing countries need to develop the technical and legal capacity for establishing IPR laws, for negotiating international and commercial licenses to the technology, and for patenting (where it is in the interest of the poor) inventions developed in their public research organizations.

*International trade.* Public controversy associated with consumer concerns over transgenic crops may produce uncertainty in markets and difficult policy issues for countries that wish to build biotechnology capacity while exporting to regions that do not accept GMO food products, such as Europe. Some developing countries may have to decide whether to give up opportunities offered by transgenic technology or give up their ability to export to European markets.
Lessons Learned

The World Bank has invested about US$50 million in financing agricultural biotechnology, of which US$20 million has supported transgenic research in India. Through financing from the Global Environment Facility (GEF), the World Bank also supports biosafety capacity building (box 2.27).

Box 2.27 World Bank investments in biotechnology and biosafety

- To date, investments in agricultural biotechnology total about US$50 million through agricultural research and development projects.
- Since 2003, the Bank has served as the implementing agency for biosafety projects funded by the Global Environment Facility in Colombia and India.
- Regional biosafety projects are under preparation in Latin America and West Africa.

Source: Authors

Current biotechnology investments under Bank projects focus on strengthening public sector research organizations to serve smallholder farmers and are quite modest when compared to large investments by private companies focused on products for commercial agriculture. Key lessons are that:

- While potential benefits from applying new tools to appropriate productivity and quality traits justify strong support for biotechnology, it is important for the public sector to remain impartial and ensure that potential risks are considered, understood, and addressed before proceeding with any biotechnology investment.
- Investment in biotechnology needs to be driven by its ability to solve agricultural problems, and priority for such funding should be within the overall national research strategy that assesses tradeoffs with, and complementarities from, other areas of research.
- Public dialogue is very important. Most countries underinvested in dialogue prior to undertaking GMO research and testing. The lack of dialogue contributes to controversies and slows the release and uptake of valuable technologies.
- No broad generalizations can be made about the risks of GMOs, and evaluation and decision making must occur on a case-by-case basis, reflecting the particular traits and economic and ecological situation.
- If the benefits of biotechnology in poor countries are to reach farmers and consumers, national and international public sector groups will have to support research, access to proprietary technologies, and the development of appropriate regulatory frameworks for public and private research and technology transfer.

Recommendations for Practitioners
In many countries, investments in applied and adaptive research on the use and application of noncontroversial biotechnologies will be appropriate, targeting plant tissue culture, micropropagation, molecular diagnostics of crop and livestock diseases, and (possibly) embryo transfer in livestock. Public investment in GMO research and/or evaluation may be appropriate when it is clearly targeted to Bank and country objectives, especially poverty reduction (box 2.28).

Depending on the size of the scientific community, capacity in biotechnology, and stage of development, support can range from using resource-intensive gene discovery technologies to transferring licensed gene sequences to local varieties through transformation methods or a crossing program.

Such investments should:

- Be based on country assessments to identify opportunities and limitations on biotechnology investments.
- Support capacity building for biotechnology research within the framework of a well-articulated national policy and strategy.
- Target high-priority problems that are best solved through biotechnology rather than conventional research methods.
- Give prior consideration to costs and tradeoffs in generating technologies locally rather than drawing on regional and international collaboration to develop and/or import appropriate tools and technologies.
- Prior to undertaking biotechnology research, develop a sound biosafety framework with its regulatory environment and monitoring capacity. This framework may be able to draw on regional capacity to evaluate and manage risks and benefits. This capacity also must be reviewed before research is funded.

**Selected Readings**

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.


**References Cited**


This investment note was prepared and updated by Eija Pehu, with input from the Sustainable Agriculture (SASKI) Thematic Team of the World Bank.
Design and Implementation of IPR Regimes to Support Plant Breeding in Developing Countries

The past few years have seen increased attention to the strengthening of IPRs in plant breeding. The number of countries that grant such rights has grown, the types of inventions that can be protected have expanded, and a broader scope of protection is offered by extant IPR systems in different countries. The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS 1993) of the WTO requires all WTO members to introduce at least a minimum level of protection in their national laws for plant varieties and inventions in biotechnology. Least Developed Countries have until 2013 to bring their national IPR laws fully up to the TRIPS standards, but bilateral trade agreements often include strict IPR clauses that go beyond the minimum requirements agreed upon in the WTO. These developments towards strengthened IPRs arise from a trade perspective rather than from a perspective of increasing innovation in the developing countries concerned.

Countries need to decide the type and strength of protection granted in the plant breeding sector, and they must design effective and efficient implementation rules and infrastructure. Throughout these processes, they have to create ownership with a wide range of stakeholders, which is a prerequisite for effective implementation.

TRIPS is just one international agreement that relates to regulatory systems affecting plant breeding. Others include the Convention on Biological Diversity, the International Treaty on Plant Genetic Resources for Food and Agriculture, and discussions at the World Intellectual Property Organization (WIPO) in the Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge, and Folklore and regarding the Substantive Patent Law Treaty.

This investment note, derived from five case studies in China, Colombia, India, Kenya, and Uganda (Louwaars 2005), concentrates on the requirements arising from the TRIPS Agreement and the IPR-related trade discussions. It provides a brief introduction to the regulatory options and implementation strategies that are available to countries, and it discusses the role that development organizations may assert in supporting those countries.

Policy and Regulatory Issues

Plant breeding research and seed provision are vital industries that need to be fostered and stimulated. Plant breeding is important for food security at the local and global levels; the ability of adapted varieties to cope with environmental stresses contributes to strategies for sustainable agriculture and to the livelihoods of the rural poor. The provision of productive options for commercial farming is vital for wider economic development.

Patents have been used to support innovation for several centuries, and since the Paris Convention of 1883, they have been used in more harmonized ways. For various reasons,
plant varieties and “methods of agriculture” have been excluded from patentability until recently, when a few countries, notably the USA and Japan, began granting such patents on varieties. More countries provide protection through a specially designed system, called “plant variety protection” (PVP) or “plant breeder’s rights,” which developed in Europe from the 1930s onwards. Some 60 countries have subscribed to a harmonized system of PVP under the Union for the Protection of New Varieties of Plants (UPOV). The UPOV Conventions provide the most widespread model for PVP, but they are not the only possible option for designing a PVP system. Even within these Conventions there is a fair degree of flexibility that developing countries must appreciate and take advantage of if they are to design PVP regimes. Of particular importance are issues related to farmer seed saving and exchange and the access to protected varieties for further research and development. Table 2.5 summarizes key choices in the design of a PVP system.

There is no blueprint advice for policy makers on how to design the ideal IPR system for plant breeding and at the same time support seed systems and rural development.

IPR regimes for plant breeding increasingly include attention to patent systems, particularly for biotechnology. Most of the genes and tools used in the development of transgenic crops are patented, at least in the major OECD countries. Even many of the diagnostic and selection processes used in conventional plant breeding are patented, and their protection has implications for researchers’ ability to use these tools and to release varieties based on these techniques. Developing country experience in the management of patents for biotechnology is still at a very early stage.

Table 2.5 Key choices in the design of a PVP system

<table>
<thead>
<tr>
<th>Factor</th>
<th>Arguments for a restrictive interpretation</th>
<th>Arguments for a less restrictive interpretation</th>
<th>Relation to UPOV 1991</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed saving</td>
<td>A country may not attract high-value export crops, such as floriculture, if seed saving for these species is not restricted.</td>
<td>Seed saving of field crops is part of farming practice. It is very difficult to enforce seed saving restrictions in these cases.</td>
<td>If a crop is not specifically exempted in national legislation, UPOV 1991 imposes seed saving restrictions.</td>
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<tr>
<td>Seed exchange</td>
<td>Widespread informal sale of seed of protected varieties (especially by large commercial farmers) is a disincentive to commercial seed activity.</td>
<td>Seed exchange and informal sale among small-scale farmers is customary and difficult to control. Large-scale informal seed sale can be controlled by appropriate seed regulation.</td>
<td>Legislation consistent with UPOV 1991 does not allow any type of seed exchange of protected varieties among farmers.</td>
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<tr>
<td>Scope of protection of</td>
<td>Restrictions on</td>
<td>Both public and</td>
<td>Supports the use of</td>
</tr>
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### Importance of IPR for Seed Sector Development

The challenges for national policy makers are to:

- Design and implement IPR systems that respond to the needs of the breeding and seed production sectors. These needs may be very different between countries and between sectors within a country (for example, for cash crops versus subsistence crops).
- Bring the national implementation of the different international agreements in line with national development policies. Standard models for IPR legislation may affect current policies to support rural livelihoods, food security, and Farmers’ Rights.

### Source: World Bank 2006
• Realize that well-designed IPRs may help stabilize the industry, protect companies from competitors that could misappropriate their varieties, and may also make foreign seed companies more confident in sharing varieties with domestic partners. Even so, commercial seed industries have developed in several countries, including India and Uganda, in the absence of IPRs (other than trademarks), and stakeholders in the industry have expressed the view that other mechanisms are at least as important.

• Carefully design the role of public research institutions. Public institutions may regard IPRs as a way to earn much-needed revenue to compensate for budget cuts from public sources. Revenue generation through IPRs may, however, eventually reduce the research investment in less commercial crops and reduce research targeting the needs of remote and resource-poor farmers.

Other mechanisms that may support the commercial seed sector include:

• **Biological protection methods.** Hybrid technology makes replanting of seed unprofitable for farmers and thus increases the market for seeds. It has been applied to maize and a number of vegetables, and it is now one of the key technologies spurring seed industry development in Asia for crops such as rice and pearl millet. Genetic use restriction technologies operating at the variety level (V-GURTS, also dubbed “terminator technology”) have the potential to become an exceptionally strong technical protection mechanism.

• **Regulatory mechanisms,** such as conventional seed law and, more recently, biosafety regulations, can streamline seed industry development and support credible suppliers.

• **Legal (contract law) and commercial (business practices) mechanisms** are at least as important for private sector development as the regulatory mechanisms just mentioned. In addition, enforceable contracts are a prerequisite for effective protection of IPRs.

IPRs should not be considered a silver bullet for commercial seed industry development.

**Implementation and Enforcement Issues**

Few developing countries have begun to implement PVP, and little guidance on appropriate strategies is available. Three key decisions must be made on administrative and technical requirements for granting the rights and for enforcing them.

*First,* a PVP system requires the creation of an administrative office and possibly variety testing facilities, which entails considerable investments of financial and human resources. Some countries will find it difficult to identify staff with sufficient scientific and legal skills for such tasks, and the opportunity cost of redeploying trained personnel (for example, the release of experienced plant breeders for variety testing) must be considered. Policy makers must carefully examine how the costs of establishing a PVP administration can be minimized. Several areas deserve attention:
• Cost considerations strengthen the argument for a phased introduction of PVP, concentrating first on high-priority crops and areas where commercial seed supply can be stimulated relatively easily.

• International harmonization of administrative and technical requirements can reduce costs for both the PVP authority and the applicants through joint testing and through accepting foreign test reports.

• A PVP authority can also assign part of the responsibility for variety testing (to determine whether varieties meet requirements of distinctness, uniformity, and stability) to breeders themselves, which may save some costs. However, this option may put smaller domestic plant breeding firms at a disadvantage.

• Attention should be given to establishing an appropriate fee structure for PVP. While cost recovery is certainly a worthwhile goal, it must be balanced against the dangers of excluding applications for crops with relatively small seed markets or varieties from companies or institutes that may not be able to afford large fees.

Second, IPRs are private rights, so most of the responsibility for enforcement rests with the rights holder. The difficulty (and political sensitivity) of enforcing rules on seed saving or local exchange provides an important argument for caution in establishing strong rights. Even in cases involving competing commercial firms, courts are often unprepared to interpret the infringement, particularly because of the biological nature of the protected subject matter. Enforcement difficulties can undermine confidence in a PVP system, however, and implementation of IPR regimes must therefore include attention to strengthening the court system’s knowledge of IPRs in plant breeding.

Third, a PVP system will not meet its goals if it is not supported by the full range of stakeholders. Breeders, seed producers, traders, and farmers need to understand the objectives of the system in order to comply with the rights and obligations associated with it. The development of a PVP system should thus include an extensive information campaign involving all stakeholders.

Protecting Biotechnology

Although patents are not a reasonable option for the protection of plant varieties in developing countries, IPRs in biotechnology justify attention to national patent regimes and their implementation. Policy makers have to develop clear ideas about the patentability of living organisms and their components—that is, they must define the scope of protection of product and process patents that might extend to plant varieties and seeds. Most national patent offices will need to build their capacity to deal with such patents, translate policies into clear guidelines, and implement them. Legal options include excluding product patents on genes and/or placing limitations on the scope of protection. In the first case, a combination of biosafety regulation, seed laws, and PVP may offer adequate protection for transgenic varieties, at least in their early stages of deployment in developing countries. The second option is used by several EU countries, where the farmers’ privilege and the breeders’ exemption for transgenic varieties are valid even when the scope of a biotechnology patent would normally disallow them.

Lessons and Recommendations
• IPRs are too important to be used as bargaining chips in trade negotiations.
• IPRs should not be considered a silver bullet for commercial seed industry development. An IPR regime, on its own, is unlikely to provide the incentives that elicit the emergence of a robust plant breeding and seed sector. Attention to other institutions and the provision of an enabling environment are also necessary.
• No blueprint advice is available to policy makers on how to design the ideal IPR system for plant breeding, because seed systems differ widely among countries, within countries, and between crops and regions. Rights that are excessively broad in scope may obstruct the flow of technologies to resource-poor countries and farmers. IPRs may contribute to the development of commercial seed systems in certain sectors and they may assist in the creation of effective public-private partnerships.
• Several sui generis models are available, including the UPOV Conventions. The most important options include: seed saving, seed exchange, the scope of protection, the breadth of coverage, and the relation of PVP and patents to the concerns of Farmers’ Rights.
• International harmonization of IPR laws should be encouraged when it supports national goals; harmonization at the implementation level may be cost effective and save on human resources.
• There is no need to establish an exceptionally rigid or comprehensive IPR regime in the early stages of seed system development. Legislation should be designed with considerable flexibility so that IPRs can be adjusted to match the evolution of the seed system.
• The interests of different groups of farmers may be served, either by providing a minimum level of protection and adding additional rules for specific crops or farmers (for example, export crops can be protected following the UPOV 1991 model and subsistence crops following a less restrictive system), or by designing a stronger IPR system with carefully delimited exceptions. For instance, smallholder farmers may be free to save their own seed of protected varieties, whereas commercial farmers are not (as in the EU).
• Farmers and their organizations need to prepare themselves to be constructively involved in national discussions about the regulatory options and implementation mechanisms for IPRs in agriculture. The concept of Farmers’ Rights gives them a formal role in such debates. Farmers’ organizations need to deal with the differing interests of commercial and subsistence farmers.
• Policy makers must also consider cost-effective means for implementing an IPR regime. International or regional harmonization of administrative procedures and testing methods and standards can significantly reduce costs.
• Policy makers must also ensure that the IPR system is consistent with enforcement capabilities in order to develop a credible system.
• An IPR system to support plant breeding will only work if all stakeholders, including breeders, seed producers and traders, farmers and their advisers, and the judiciary are well aware of their rights and obligations. Particular attention is also needed to ensure that policies encourage NARIs to fulfill their public sector mandate while taking advantage of IPRs to gain access to technology, guide the diffusion of their varieties, and, where appropriate, earn royalties. National and international agricultural research institutions need to develop clear strategies for using
IPRs for their own inventions and for managing third-party IPRs in their R&D work. They will require access to legal, business, and administrative support.

The key to effective implementation is knowledge among all stakeholders—including breeders, seed producers, farmers and the judiciary—of their rights and obligations under IPRs.

The Role of Development Agencies

IPRs in agriculture are new to many developing countries. Development agencies may be able to support the development, implementation, and enforcement of suitable systems, with a view to providing broader support to seed system development. Development agencies may support countries by

- Supporting stakeholder consultations: providing a platform for consultation and assisting different stakeholders to develop their views.
- Supporting institution building: specifically, support the building of IPR institutions themselves, to make registration and testing of new varieties transparent and efficient and to encourage regional harmonization.
- More specifically, supporting national and international agricultural research institutions in developing clear institutional policies and skills to use IPR systems well and to develop public-private partnerships for effectively negotiating access to technology and avoiding legal recourse.
- Supporting the development of human resources, such as the development of technical, administrative, and legal capacities in IPR institutions (both for PVP and patents), including the judiciary, and in public and private breeding programs. Short training courses, opportunities to share experiences within the region, and Internet-based information packages may be considered.
- Supporting the development of extensive information campaigns to help all stakeholders understand their rights and obligations under the new system, in order to support compliance and effective implementation.
- Stimulating further research to monitor experience with IPRs in developing countries and examine issues related to the cost-effective management of IPR regimes.

Development agencies may include IPR issues in their ongoing programs—for example, in their programs to support national and international agricultural research and extension, agricultural policy, and agribusiness development.

Selected Readings

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.


References Cited


This investment note was written by Niels Louwaars of the Centre for Genetic Resources, Wageningen University, the Netherlands, with input from Riiikka Rajalahti and Eija Pehu.
Brazil: Spill-ins from Foreign Research and Development Laboratories

Brazil’s agricultural sector has been an important source of economic growth. Today the sector faces the multiple challenges of increasing productivity while addressing pressing poverty, unbalanced regional growth, and natural resource constraints. Agricultural research is important for increasing productivity and reducing rural poverty.

Brazil has a broad agricultural research system. In the mid-1990s, the national research agency (Embrapa, the Brazilian Agricultural Research Corporation) had 2,064 researchers and an extensive infrastructure. State (provincial) research systems had an additional 2,395 researchers, and university teaching and research faculty numbered over 4,000. This capacity was underutilized, however, and adequate operating funding and linkages between institutions were lacking. As in many other developing countries, the need to include private sector research, to increase competition, and to make research demand-driven and responsive to farmer needs was recognized. There was a need to strengthen domestic capacity by capitalizing on research resources outside the public sector and by encouraging technology and scientific spill-ins (or activities) from advanced research institutes.

**Project Objectives and Description**

In 1997, the Agricultural Technology Development Project led by Embrapa was initiated to increase the efficiency and sustainability of resources in the Brazilian agricultural research system. This goal was to be accomplished in four ways, by: stimulating development of a more integrated and diversified national agricultural research system, with greater participation of the private sector; increasing the role of clients in defining research and technology transfer priorities; refocusing public sector research on public goods, such as research on family farms, natural resource management, and upstream technology activities not attractive to the private sector; helping Embrapa to address issues of decentralization and diversification of the research system; and facilitating increased scientific spill-ins from advanced research institutes.

Nearly two-thirds of project funding allocated to a CRGP acted as a catalyst for the long-term transition of the research system toward a diversified system of agricultural research and technology transfer. A committee with representatives from various public, civic, and private stakeholders, including farmer groups, selects the best research proposals.

A companion institutional capacity-building program aims to increase the capacity of institutions to bid for grants. It includes support for research management improvements, training, special studies, public-private partnerships, and international collaborative linkages.
research programs. The international collaborative linkages program includes a virtual external program for “Embrapa’s Foreign R&D Lab,” referred to as LABEX.

Under the LABEX program, promising Brazilian senior scientists in mid-career are assigned to research programs in advanced research institutions in industrial countries. These scientists observe the latest scientific developments in their field, develop joint programs for future collaboration, and facilitate interaction between research teams in areas relevant to the Brazilian agro-livestock sector. LABEX was initiated as a cooperative program between Embrapa and the Agricultural Research Service of the U.S. Department of Agriculture (USDA-ARS). The LABEX program operates in the USA and France.

**Benefits and Impacts**

Program achievements include:

- Impressive growth in the number of institutions partnering in agricultural research execution and financing in Brazil has helped to overcome a major challenge in technological innovation and has fulfilled a basic condition for national competitiveness—broad-based participation that includes the private sector. Some 258 institutions are involved in executing subprojects, including 100 private firms, and another 400 entities participate in collaborating roles.

- The project has attracted counterpart investments from diverse partners, including private enterprises. It has raised awareness that closer involvement with research is important and galvanized the development of innovative agricultural technology in Brazil. The 139 research projects (representing 460 grant-based, independent research subprojects) already under contract, following open bidding events, represent some US$45 million, of which Bank financing is US$22 million and US$23 million is counterpart funding from the 258 participating bodies, including Embrapa. Of this, 42 percent (US$10 million) is the counterpart contribution of other partners, including private sector partners.

- The ground-breaking LABEX system, initiated in 1998 through Embrapa’s collaboration with USDA-ARS, has created the strongest formal agricultural research collaboration in the world. Its success prompted the creation of LABEX-France in collaboration with Agropolis in Montpellier, which is the first example of a developing, Southern Hemisphere country with a research presence in Europe, working on tropical agriculture.

- The project helped 365 researchers and technicians from Embrapa and Brazilian state research organizations enroll in project-financed formal graduate and postgraduate programs (287 within Brazil and 78 outside Brazil).

- In conclusion, benefits and achievements can be summarized in broad terms as including: more effective interaction between scientists and national agricultural research institutions; greater openness of Embrapa to the national and global scientific community; an increasingly demand-based definition of research priorities; more decentralized national research efforts; and improved quality of scientific research in general owing to the standards and selectivity of the program.
Institutional spillovers can also be identified:

- The structure and operational features of the competitive grant system have changed the scientific culture in Brazil. Research quality has improved owing to evaluation and review of R&D projects, changed procedures for preparing research projects, and the introduction of systems similar to PRODETAB at the state level.
- One of the greatest institutional impacts is the reformulation of Embrapa’s own planning systems by introducing the competitive element in research development. Today Embrapa’s scientific programming is more focused and guided by broad, national themes and by demands and opportunities generated by the new economic and social regime in Brazil. The competitive review and selection of research proposals through a bidding process is now routinely incorporated in the annual formulation of Embrapa’s research agenda.

Lessons Learned and Issues for Wider Applicability

Brazil has an extensive and well-developed agricultural research capacity. Rapid advances in science and limited research funding, even in the best of circumstances, make it essential to avoid duplication of effort and to access new technologies and scientific knowledge in the most cost-effective way. This requires international exchanges and linkages.

In the past, bilateral grant aid provided support for international training, collaborative research, and institutional development. In most countries, this support has declined, leading to a growing isolation of research scientists. The LABEX program seeks to leverage Embrapa resources by developing collaborative research, education, training, and outreach efforts in areas of mutual interest with international research institutions. This strategy is likely to be relevant to many other countries, especially those with more limited research and educational capabilities than Brazil.

<table>
<thead>
<tr>
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| Contact Point | Luis O. Coirolo  
The World Bank, Edificio SUDENE, Sala 13S-021, Cidade Universitaria, 50670-900 Recife, PE, Brazil  
Email: lcoirolo@worldbank.org |

Colombia: Decentralized, Demand-Driven, Competitive Technology Generation

By the early 1990s, the institutional model of the traditional public system of agricultural research and extension in many Latin American countries had declined in its effectiveness. Despite working fairly well in the past in delivering technology for major commodities, the model faced new challenges to which it was unable to respond. Challenges included the development of sustainable production systems, resource conservation, processing, and markets and exports. These problems resulted partly from an overly centralized, highly bureaucratic research system that was not well linked to its clients.

In the early 1990s, the Government of Colombia committed itself to decentralizing technology development and transfer to bring applied R&E closer to the priority problems of target beneficiaries, who would participate in characterizing, prioritizing, and solving their problems.

Project Objectives and Description

In 1995, the National Agricultural Technology Development Project (PRONATTA) was designed with World Bank support to assist this decentralization process, by offering funding for regional research and institution building. The project’s four key objectives were to promote a pluralistic technology system, support demand-driven and decentralized approaches, diversify financing through cofinancing by users and research providers, and provide incentives for reforming public R&D. Two program components involved:

- Creation of a competitive fund, in which resources are assigned to proposals responding to needs of small rural producers.
- Institutional development, aimed primarily at building local institutional mechanisms to allow stakeholders, particularly small-scale producers, to participate in addressing problems of agricultural system productivity and competitiveness.

For assigning funds, the competitive fund used four criteria: the use of a systems approach, addressing sustainability, participation of end-users in technology development, and building farmer capacity.

Implementation was decentralized to five regions where local “nodes” were established and linked into regional “networks” to coordinate research activities. The nodes are informal groups open to research institutions, farmer groups, NGOs, private sector, and officials of departmental secretariats of agriculture. A total of 340 organizations have participated in the nodes, and an additional 160 in thematic networks that operate in...
parallel with the nodes. Nodes develop lists of priority research issues and project profiles, and at the network level consolidate these for the region. These priorities are submitted to the PRONATTA Regional Coordination Unit.

Competitive project selection for grants is done largely at the regional level. Calls-for-proposals are distributed widely. Proposals are screened for eligibility by PRONATTA’s coordination unit. Regional technical panels, using priorities established by the regional networks, evaluate the proposals, which are ranked by priority and submitted to the PRONATTA central office for funding within the limits of available funds.

The program has maintained high-quality standards for awarding grants. For the six calls for proposals over the life of the project, approval rates for proposals ranged from 13 to 22 percent. Some 636 grants were awarded out of 3779 proposals submitted.

Benefits and Impacts

Within two years, the competitive fund expanded rapidly to cover all five regions of Colombia and has funded over 600 projects at an average cost of US$50,000. The program has been widely recognized for its transparent approach to the awarding of grants and for funding high-quality, relevant research. Of all projects funded by PRONATTA, 96 percent were rated satisfactory. Research projects that received funding covered several subsectors: agriculture (63.5 percent), animal husbandry (17.1 percent), forestry (3.6 percent), fish and aquaculture (5.3 percent), natural resources (1.6 percent), and multiple subsectors (8.8 percent).

A total of 179 implementing agencies have been involved in project execution. The Colombian Institute for Agricultural Research has received 39 percent of the grants; NGOs, 11 percent; universities, 9 percent; producer associations, 6 percent; other public institutions, 4 percent; other private agencies, 5 percent; and alliances between different institutions, 26 percent. The resources leveraged in cofinancing research amounted to 60 percent using the competitive funding approach.

PRONATTA research projects have demonstrated their impacts by raising productivity and increasing the adoption of sustainable management practices among small-scale producers, especially through reduced applications of agricultural chemicals and greater use of improved soil management practices. About 150,000 direct beneficiaries have adopted technologies introduced by PRONATTA. The number of indirect beneficiaries exceeded 200,000. A subsequent impact evaluation of completed projects found that the vast majority are producing or are likely to produce significant short- to medium-term benefits, mostly for small-scale producers. Benefits far exceed the cost of the investments. Thirty-two percent of small-scale farmers adopted environmentally sound technology through this project.

Lessons Learned and Issues for Wider Applicability

The design of competitive research grant programs should emphasize transparency in operation; involve farmers and other beneficiaries in priority setting, evaluation, and
selection of projects; establish sound monitoring and evaluation systems; and develop mechanisms to enhance portfolio coherence. Major lessons learned from the PRONATTA experience are that:

- A competitive fund can draw a wide variety of research and extension service providers into the national research system, thus building a research system characterized by greater diversity, both in the demand and supply of technology and innovations and in its varied sources of funding. It is also an effective way to leverage idle resources.
- Decentralized execution of a competitive grants program is key to substantively involving local people in an applied and adaptive research program. Competitive grants are suitable instruments for reducing regional inequity, but decentralized implementation must always be accompanied by a strong component of institutional development to strengthen capacity in less competitive regions.
- Competitive funding is a good means of promoting alliances among different actors in the agricultural innovation system. Such alliances permit interaction among a range of actors in preparing, presenting, and implementing projects, thereby improving interaction between different social groups and disciplines and leading to stronger and more demand-driven research proposals.
- Local institutional capacity building for client groups, local government, and potential service providers is important for promoting competition. Representative involvement of all sections of farming groups is not a simple task, and it depends on community dynamics. Effective involvement requires long-term investment in institutional development and community participation.

Projects similar to the PRONATTA program are being implemented in Peru, Ecuador, Nicaragua, Brazil, Mexico, and some countries in Europe and Central Asia.

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<td>Matthew A. McMahon The World Bank, 1818 H Street, NW, Washington D.C. 20433 Telephone: (202) 473-8586; Email: <a href="mailto:mmcmahon@worldbank.org">mmcmahon@worldbank.org</a></td>
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Ecuador: Strategic International Alliances for Capacity Building and Research

By the mid-1990s, Ecuador’s agricultural research system, based principally on a public sector research institute, faced interrelated problems of low productivity, a funding crisis, and attrition of scientists. At the same time, technological and management innovation was needed to improve the productivity and competitiveness of Ecuador’s important agricultural sector. Modernization of production systems and sector institutions were essential if the sector were to compete in regional and global markets. As a result, the government undertook a program of institutional reform, with the objective of strengthening research capacity in a variety of public and private organizations, increasing efficiency of research, and improving linkages to clients.

Project Objectives and Description

The Agricultural Research Project had three major objectives: to introduce a competitive research grants program (CRGP), to develop partnerships with international science institutions, and to strengthen national research institutions. The government contracted a private firm to manage the CRGP within policy guidelines established by the government.

Competitive grants for strategic partnership alliances with international research organizations were financed in parallel with grants for individual research activities. Both followed the same competitive procedures and targeted development of local institutional capacity for research in key thematic areas. Institutions submitting proposals had to demonstrate a commitment to cofinancing a substantial and sustainable program in identified priority areas for research. In almost 70 percent of the financed CRGs, public sector lead institutions predominated, whereas in others NGOs, producer organizations, and even private companies were financed.

Strategic Alliance Grants (SAGs) were also authorized to improve higher education (at the master’s level) in agriculture. Strategic alliance grants were larger than research project grants (average US$321,000 versus US$62,000). Participating institution cofinancing contributions averaged 45 percent of total program costs. Cofinancing contributions from participating institutions averaged 50 percent of total program costs of the research projects and 41 percent of the SAGs.

The SAG Program was designed to facilitate access to relevant technologies and technical expertise available internationally. The technology spill-ins resulting from this program represent a cost-effective means of improving the technology base for Ecuador’s agriculture. The competitive selection procedure requires evidence of institutional commitment to long-term work in the program area. It also allowed Ecuadorian
institutions to set their own priorities for program development and to select their own partners for alliances.

Benefits and Impacts

The SAGs financed six alliances for postgraduate program development in agricultural subjects. Six Ecuadorian universities participated as lead institutions and developed alliances with eight foreign universities, six international research centers, four local universities, and four other institutions.

Seven SAGs for agricultural research financed partnership development for three Ecuadorian universities, the public research institute (with two research alliances), an NGO, and a producer group. Research themes included fruit processing, regional agribusiness development, soils, production systems, biotechnology, medicinal plants, and soil salinity management. Alliances involved six foreign universities, four international research centers, three local universities, and ten other institutions, including various client groups.

The strategic alliances have allowed local organizations to draw on resources and technical expertise from international centers of excellence and have encouraged long-term relationships with partner research and educational institutions and with client groups. They have proven effective in developing local capacity and providing efficient access to spill-ins of scientific knowledge and the latest technologies.

Competitive selection procedures helped to identify institutions with sufficient capacity that were interested in and committed to developing as centers of excellence for specific thematic issues. Adding education programs to the SAGs provided for longer-term strategic capacity development for the country.

Lessons Learned and Issues for Wider Applicability

Financing to develop research capacity is likely to be needed in most countries where CRGPs are being introduced. Such capacity building can be financed through core funding for a research agency, although, as in Ecuador, competitive procedures may be useful in identifying institutions with a commitment to a particular field of research and a core capacity on which to build. This latter approach has proven feasible even in a country with a small research community, as in Ecuador.

A two-stage procedure had to be adopted in implementing CRGPs: following an initial review of “profiles,” proponents of satisfactory profiles were invited to prepare detailed research proposals. Considerable technical assistance was also needed on budgeting and other financial aspects of preparing proposals. Overall the CRGPs proved to be an important tool to ensure that researchers and institutions prepared high-quality proposals and install good monitoring and evaluation and financial and reporting systems.

One innovation introduced while supervising research projects was the formulation of a “reference group” made up of members of the target group, other scientists, local
industrialists, and extension workers, which guided the project’s implementation and ensured its relevance. A survey examining how a sample of these groups functioned indicated that their value was closely linked with the commitment of individual members and that it may be useful to form the groups when individual research projects are being designed.

Competitive selection of projects to be financed also allows participating institutions to provide cofinancing, thus increasing total funding available for research and strengthening the overall system.

The emphasis on partnerships and joint proposals, particularly between public and private sector organizations, promotes greater awareness of reciprocal capabilities and contributes to better-informed proposals.

The CRGP approach has helped researchers start to see themselves as competitors for resources rather than passive recipients of research grants, which in turn has improved awareness of the need to accommodate research to national, regional, and sectoral demands.

Because CRGPs are not naturally self-sustaining, the establishment of a competitive, demand-driven system beyond the project phase must be an integral part of project planning.

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<td>Contact Point</td>
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</table>
India: Focus on Biotechnology

Despite its self-sufficiency in food grain production, India faces continuing challenges in sustaining agricultural growth rates. Developments following the green revolution have brought into sharp focus concerns relating to productivity, sustainability, and environmental protection. Advances in biotechnology offer great scope for improvements in crops, livestock, and aquaculture. For example, the development of transgenic crops with increased yields and improved nutritional qualities, and the development of diagnostic kits for plant and animal diseases, are areas with considerable potential.

Building domestic capacity and advancing research in biotechnology are consequently critical to sustaining agricultural growth, and the use of research providers that are not part of the national agricultural research system is considered essential for improving the outcomes of these activities. Links to international researchers are also necessary, given the rapid pace of international biotechnology research.

Project Objectives and Description

The overall objectives of the National Agricultural Technology Project (NATP) were to: improve the efficiency of the Indian Council of Agricultural Research (ICAR) organization and management systems; enhance the performance and effectiveness of priority research programs and of scientists in responding to the technological needs of farmers; and develop models that improve the effectiveness and financial sustainability of technology dissemination with greater accountability to, and participation by, farming communities. The project sought to change the research agenda from being commodity- and budget-driven to one that was disciplinary- and demand-driven. The process used for developing scientific capacity included:

- Establishing teams of excellence.
- Training scientists.
- Funding research through competitive grants that were open to public, private, and community organizations.

Teams or centers of excellence, consisting of a prominent individual scientist or group of scientists within existing institutions, are given administrative and financial autonomy to facilitate contracting and collaboration with a range of partners. This approach was designed to draw in and disseminate new ideas and to pilot new forms of decentralized management of research units/activities. Because of rapid developments in science, strengthening international linkages is important to improve the quality of science and the capabilities of scientists. Funds allocated under this subcomponent promote links with institutions having complementary interests/expertise.
Within the NATP, biotechnology investments seek to improve crop, livestock, and fisheries productivity through research to develop transgenic crops with inbuilt resistance/tolerance to biotic and abiotic stresses and research to reduce the use of pesticides. The project also aims to develop diagnostic kits for early disease detection in animals and aquaculture, to develop vaccines for better health management in animals, and to use biotechnology tools for processing and adding value to crops by increasing the shelf-life of fruits and vegetables.

The project established a Biotechnology Advisory Group (BAG) composed of scientists from public and private agencies to provide additional views in establishing research and training priorities. The BAG group was designed to brainstorm various issues related to biotechnology, guide ICAR, and review proposals submitted both through the sponsored and competitive route. The project team considered it important to establish such an advisory group, because ICAR institutions are the weakest amongst various agencies involved in biotechnology research, such as the Council for Scientific and Industrial Research, universities, and the private sector. During 1998-2003, the project:

- Established teams of excellence in the area of plant biotechnology, viral biotechnology, and animal biotechnology.
- Trained 200 scientists annually in state-of-the-art knowledge on crop and animal biotechnology.
- Developed transgenic rice, cotton, mustard, muskmelon, potato, and pigeonpea.
- Used competitive grants to fund high-quality research in biotechnology.
- Established management systems to provide for rigorous monitoring and evaluation, including progress on execution of research activities.

Benefits and Impacts

There has been significant progress in developing capabilities for research on transgenic plants, with major successes in developing transgenic rice and cotton with the *Bacillus thuringiensis* (Bt) gene, which confers insect resistance. Transgenic rice was tested in confined field trials in 2004. In addition, two genes for leaf rust resistance, Lr 19 and Lr 28, were tagged for the first time using molecular markers. They have been combined in one genotype providing strong resistance to leaf rust in wheat. Another major achievement has been the characterization of genomes of plant and animal viruses, enabling the development of plants with in-built resistance to insects and viruses and improved viral detection methods in livestock and aquaculture. The development of diagnostic kits will help detect plant viruses in citrus, potatoes, and bananas, as well as diseases in livestock.

Lessons Learned and Issues for Wider Applicability

The progress on biotechnology research and its initial results illustrate that:

- Research programs focused on key problems and subject to rigorous and transparent monitoring can yield important dividends.
• Building in-house competence through human resource development and physical infrastructure can result in rapid progress and quality research outputs.
• Competitive research grants, awarded through a transparent selection process and followed by good monitoring, evaluation, and impact/outcome assessment, are an effective mechanism for financing high-quality research, undertaken by multidisciplinary teams from a range of institutions.
• Competitive grants can be useful in providing research support to more young scientists and to female scientists.
• A mechanism such as the BAG could be of value to other projects supporting research on biotechnology (or any other thematic area) in countries with a weak institutional and scientific base. While ICAR has not fully exploited the potential of this mechanism, the approach has the potential to mobilize all expertise available within a country (and possibly abroad) to improve the relevance and quality of research.

In view of the substantial successes under the program, ICAR is developing major biotechnology programs based on a competitive research grants scheme. Program management emphasizes transparency, quality evaluation, and bottom-up approaches.

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India: Revitalizing Institutional Capacity in Forestry Research

The Indian Council of Forest Research and Extension (ICFRE) has been conducting forestry research in India since the colonial era. ICFRE’s activities lacked scientific and institutional mechanisms for ensuring scientific rigor, setting research priorities, ensuring a client orientation, and using research results. Management systems for staff, research activities, finances, reference libraries, and other facilities needed significant upgrading. For research, systems were needed to ensure that research addressed specific technical concerns, provided multidisciplinary perspectives, and reflected national priorities and regional needs.

Project Objectives and Description

The main objective of the Forestry Research Education and Extension Project (FREEP) was to improve forestry research capacity and quality. Other components included biodiversity conservation and government forest policy analysis and development. Specific objectives related to:

- Strengthening the capacity of national, regional, and state institutions to conduct priority forestry research, including planting stock improvement programs, through improvements to institutional management and administration programs.
- Improving the system of forestry education in research and academic institutions.
- Improving the dissemination of research findings to users of the information.

FREEP represented a successful departure from past forestry projects in that it did not focus on research as one component within a broader forestry operation, or on forestry research within a broader research operation. FREEP specifically focused on improving institutional capacity to conduct forestry research, education, and extension and to build this capacity in the national research system.

Benefits and Impacts

The project achieved its targets by improving the capacity of ICFRE to plan, prioritize, and carry out forest research. Specific targets achieved included:

- After extensive consultation with stakeholders to identify priorities, ICFRE developed and is now implementing a National Forest Research Plan.
- Research Advisory Groups, comprising multidisciplinary experts and clients and chief scientific advisors, review research projects to ensure their scientific quality and their relevance to user needs. Increased computer literacy and improved
facilities (library, modern nurseries, research equipment) help modernize research.

- An information management system and human resource development plan facilitate program budgeting and improved staff management.
- Improved planting stock programs (in all states), small grants programs, technology licensing, extension activities and materials, and curricula reforms have dramatically increased ICFRE’s client outreach.
- The project has been quite successful in developing the “forestry knowledge and information system,” but its integration into the broader AKIS remains uncertain.

**Lessons Learned and Issues for Wider Applicability**

This successful approach to institutional capacity development in forestry research provides lessons that can be applied beyond the forestry sector and agriculture to other institutional revitalization programs, because it:

- Focused on specific activities critical to sustainable change (for example, implementation of a sound management information system, arrangements to increase interactions with clients, external peer review mechanisms, and technical oversight).
- Directly addressed core organizational weaknesses within institutions and brought about institutional change within the relatively short time-frame of one project.
- Focused on basic institutional management issues, such as finance, staffing, and administration, rather than on specific technical tasks or functions of an institution, such as specific research.
- Coordinated with broader agricultural research and information programs and institutions to give coherence to technical services for rural areas and to seek economies of scale in program operations. These policies and institutional mechanisms need to be mutually supportive in order to avoid conflicts and to enhance sustainability of technical services.

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Senegal: Making Research Demand-Driven

Evaluation of the Second Agricultural Research Project, completed in 1996, highlighted poor performance of the Senegalese Research Institution (ISRA). Despite considerable investment since the mid-1980s, with two successive Bank and two successive USAID-funded research projects, ISRA was still not responding to farmers’ needs. Management reforms, including incentive systems to reward performance and financial management improvements, remained pending. Investments in important subsectors of postharvest technology and agroprocessing had been neglected because they were the responsibility of a different research institute, the Food Technology Research Institute (ITA).

What’s innovative?
A new funding mechanism that provides for core institutional capacity building in parallel with a competitive research fund with separate funds for farmer-proposed and researcher-proposed projects, so as to develop demand orientation in research.

Project Objectives and Description

The Agricultural Services and Producer Organization Project is a shift in approach from supporting only the supply of services to supporting both the supply of and demand for services. Without strong demand from end-users, public research institutions were unlikely to make essential, but difficult, reforms to improve responsiveness of research to clients. The project sought to (1) strengthen producer organization (PO) capacity to become effective research partners and (2) establish mechanisms to make research institutions accountable to clients. The project design recognized the need for:

- Capacity building for two research institutes (ISRA and ITA).
- An alternative to “institutional” or core funding for research operating costs.
- More effective utilization of scarce human and physical resources for research.

The project established the National Agricultural Research Fund (NARF), a legally independent entity that separates its research funding function from the execution function and enables qualified entities, public and private, to access funds for research. Parallel core funding provides ISRA and ITA with funds for infrastructure, training, and management strengthening.

NARF finances research proposals submitted through two mechanisms: researcher-developed proposals related to ISRA’s or ITA’s strategic plans, and responses to calls-for-proposals issued by NARF on themes identified by end-users. The two types of proposals undergo the same two-tier screening procedure: first, by a scientific and technical committee of 15 scientific resource persons (6 from outside Senegal), who screen proposals for scientific quality, and then by a management committee with a majority of PO and private sector representatives. Once a proposal is approved, NARF signs a contract with the lead research institution.
Benefits and Impacts

The two separate funding mechanisms (core funding of research institutes and NARF-contracted research) guarantee that institutional development continues, while funding for operating costs goes directly to research teams working on projects relevant for the users, and for which teams are accountable for results. Projects are screened rigorously. Only 26 of the first 79 research proposals were approved. Projects promote collaboration between organizations with research capacity (85 percent of projects); with international organizations (12 percent); and with development agencies, such as POs, NGOs, or others (58 percent). Overall, 38 institutions have received funding under the 26 projects.

Under new funding arrangements, the Ministry of Finance agreed that government funding must cover research institute fixed costs, which can no longer be financed by International Development Assistance funds. This caused the government to recognize that it could no longer afford to support ISRA’s extensive research infrastructure and that closing redundant facilities was inevitable.

The program’s success is qualified by the fact that in its initial stage, no proposals were accepted for research on products likely to be significant for future exports (horticulture and fisheries), for basic food crops (rice), or for future technological breakthroughs (biotechnology). The Fund is therefore considering narrowing the scope for future grants to priority topics that are defined by a group of experts from within the national agricultural research system.

Lessons Learned and Issues for Wider Applicability

Sustainability of a competitive research fund mechanism depends on a manager’s ability to attract funding from other donors. For this reason, one performance indicator for the project is the number of other donors that the Fund attracts.

Research funds should be managed independently of research-implementing organizations, because of conflicts of interest. Locating funds outside government ministries allows for more flexible management.

Establishing a management committee with a majority of user representatives, responsible for the program, produces a very different dynamic than when government officials are a majority on the governing body.

Having two channels for researcher-proposed and user-requested research proposals provides flexibility and allows a program to respond both to immediate producer concerns and to opportunities identified by scientists.

The generation of sufficient proposals of good quality and relevance is a function of the research capacity of the country’s human resources, hence the importance of core funding for capacity building in parallel with a competitive fund.
Research partnerships with strong international research organizations also enhance the quality of research, but governments often object to using loan funds to finance foreign researchers. Complementary bilateral grant funding can therefore be important to finance collaboration of researchers from advanced research institutions.

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<td>Contact Point</td>
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<td>The World Bank, 1818 H Street, NW, Washington D.C. 20433</td>
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<td>Telephone: (202) 473-4994; Email: <a href="mailto:mcollion@worldbank.org">mcollion@worldbank.org</a></td>
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Romania: Competitive Grant Support for Providing Technology and Information to Private Farmers

Agriculture is a major contributor to Romania’s economy, accounting for 20 percent of GDP and about 35 percent of all employment in the country. Despite Romania’s rich natural resource base, agricultural production has been well below its potential. The abrupt change to a market economy in 1991 and the emergence of about 3.6 million private farmers had significant implications for the agricultural sector. There was an urgent need to generate, acquire, and disseminate appropriate agricultural technology so private farmers could become efficient and competitive in the new market economy. The agricultural research and extension system, which had been driven by ministries, academies, and universities, was in general disarray. Traditionally technology had been transferred directly from research institutes to managers and technicians employed by state and collective farms; no extension or advisory services were available for private farmers. The old system had been characterized by narrowly focused academic research; public sector dominance; insufficient financial resources, talent, incentives, and motivation; and too many institutions, with ill-equipped, outdated laboratories and little accountability to stakeholders.

The government’s strategy for the agricultural sector is to transform farming households into profitable farm enterprises. In this context, Romania’s accession to the EU in 2007 underscores the urgency of reforming the organization and management of the national agricultural research and extension system to improve the overall performance of the agricultural sector. The Romania Agricultural Support Services Project, while acknowledging the need for a comprehensive strategy for reforming agricultural research and extension, recognized that reform was a long-term undertaking, requiring substantial resources, and that first there was an urgent need to provide appropriate technology and information rapidly to private farmers. To meet this need, the project adopted a Competitive Grant Scheme (CGS), which provided an efficient, cost-effective mechanism for using the scarce skilled human resources and limited facilities in Romania to yield rapid results. Without the need for large investments, the grant scheme not only improved the overall performance of the agricultural sector but also helped to improve farmers’ incomes. The program encouraged and enabled the introduction of modern techniques and ideas into the research and extension system, reoriented the institutions to address issues and problems confronting farmers rather than conduct purely academic research, and ensured closer collaboration between the research and extension community and newly emerging private farms.

Project Objectives
The project sought to provide needed technology, information, and training to farmers and agroprocessors and to improve efficiency, cost effectiveness, and client relevance in the management of research and extension. To achieve these objectives, the project provided support for priority research and extension activities that would transfer proven technologies to farmers, and it developed the CGS to respond to farmers’ emerging needs.

Benefits and Experience to Date

The project achieved its proposed objectives. The number of technologies transferred and farmers who benefited was substantial, and farmers’ efficiency and profitability increased. The CGS designed under the project: (1) stimulated research institutes and universities to collaborate with farmers’ associations and NGOs in providing farmers with better knowledge and developing new, demand-driven working methods; (2) led to the creation of more than 350 farmers’ associations and strengthened the agricultural sector’s capacity to meet the challenges of EU accession; (3) built an institutional structure (the CGS Board and Secretariat) to mainstream the CGS in the Ministry of Agriculture, Food and Rural Development (MAFRD); and (4) provided a platform for farmers to benefit from new projects, particularly the EU-funded Special Accession Programme for Agriculture and Rural Development (SAPARD).

Economic and financial impact. Rates of return for subprojects varied between 46 percent and over 200 percent. The adoption of technologies disseminated by the subprojects resulted in a net increase in income per farmer of US$190-900 per year (depending on the crop), representing an increase of 42-81 percent over the net income from the same crop before the project began.

Social impact. The project had a direct impact on some 45,000 farmers, as evidenced by their adoption of the proposed new technologies. The number of farmers indirectly affected because of spill-over effects is believed to be three to four times higher. The CGS component also promoted the concept of farmer associations and highlighted the advantages for farmers in joining forces (for example, to apply new technologies or access markets).

Institutional impact. The project’s impact on the institutions dealing with research and extension was also largely positive. In the past, technology generation and acquisition were solely in the hands of the Romanian Academy of Agricultural Sciences, which operated independently of the Ministry of Agriculture and the University. The grant scheme improved the relationships and synergistic efforts between different partners engaged in research and extension, including NGOs and the private sector, which, although they had good relationships with farmers at the grassroots level, were often far-removed from the institutes and academies.

Lessons Learned

Some of the lessons learned during implementation of the CGS may be summarized as follows:
• To ensure a clear, transparent methodology for awarding competitive grants, a rigorous set of criteria and indicators should be set out in a well-designed, clearly written operation manual.

• To avoid the perception of bias, CGS Board members should come from the public and private sector and be selected on the basis of their knowledge, experience, and independence. The Chair of the Board should be an independent person with a good reputation, not representing the government or any particular beneficiary.

• To ensure that the program is demand-driven and reflects the needs of farmers, multiple beneficiaries must be involved in decision-making for setting priorities and awarding grants. For the subprojects to be implemented successfully, the smooth and timely flow of funds is critical and must occur in accordance with the contractual workplan and agreed disbursement schedules based on performance indicators.

Still other lessons include: the operational manual must be updated periodically to reflect the evolving needs and demands of the sector; training in developing good-quality projects must be provided to members of the Board, CGS secretariat, and applicants for grants; and a strong monitoring and evaluation system is essential for ensuring project success.

**Potential for Wider Applicability and Issues in Scaling Up**

Many countries in the Eastern Europe and Central Asia (ECA) Region face similar problems in providing technology and information to farmers to meet the new challenges of a market economy. Based on the experiences of Romania, a number of countries in the region—Azerbaijan, Croatia, Georgia, and Kazakhstan—have initiated similar CGS programs, and their number is increasing. Romania is already capitalizing on the experiences gained under the project in the efficiency, cost effectiveness and speed of response to farmers’ needs for technology and information. The government has started to implement a new US$50 million Bank-funded Modernizing Agricultural Knowledge and Information Systems (MAKIS) Project, designed to expand activities initiated under the Agricultural Support Services Project by supporting agricultural research institutions and advisory systems as well as strengthening food safety. In particular, the MAKIS project will assist research institutes and the agricultural extension agency (ANCA) to undertake, with full government support, the structural reforms necessary to fully achieve the efficiency, effectiveness, and client relevance objective. The participatory and demand-driven approach to applied research initiated by the Agricultural Support Services Project through the CGS will be continued under MAKIS, which will gradually mainstream CGS as one of the core activities of MAFRD.

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