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Trends in the Organization and Financing of Agricultural Research in Developed Countries

Implications for Developing Countries

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International Service for National Agricultural Research

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Foreword

The economic, social, political, and technological forces influencing research organizations in developing countries have changed over the past decade. Agricultural development is increasingly concerned with diversification, adding value, capturing markets, mixing on-farm and off-farm income, forming and entering marketing chains, improving food quality and safety, and balancing agricultural and ecological interests. New technological opportunities have arisen through the application of research approaches initially developed for other sectors: for example, many agricultural biotechnology tools have their origins in medical research, and many innovations in information sharing and communication are based on generic progress in the computer sciences.

Agricultural research organizations in many developing countries face increasing financial pressure. This is caused not only by a squeeze in government spending, but also by the belief that research should be demand driven and should be supplied from diverse sources. At the same time, the science and technology sectors of many developing countries (even relatively poor countries) are becoming more diverse. The number of research organizations is increasing, more policy and funding bodies are involved, stronger stakeholder organizations are demanding a bigger say in determining the research agenda, and development projects are increasingly turning to researchers as a source of knowledge. Decentralized government is complicating the issues, devolving more power to regional and local levels of government, whose influence on the local research agenda may be at variance with the interests of central government.

Research managers and policymakers in developing countries must come to grips with these new forces. Above all, they must recognize that agricultural development is not the automatic outcome of a linear process of knowledge creation, application, adaptation, and transfer, but rather a far more complex, less predictable process that is integrated with research but subject to larger forces beyond the control of any one country or institution. Many research organizations in the developing world are in the process of redefining themselves in response to the new opportunities and threats posed by these forces.

A similar process of change in the orientation and functioning of agricultural research is already well advanced in the developed countries, where the forces mentioned above were felt somewhat earlier. To understand the implications of the process for developing countries, the Cooperative Program for the Agricultural-Technological Development of the Southern Cone (PROCISUR) of South America undertook a project titled Organization and Management for the Integration of Agriculture, Livestock, and Agroindustrial Technology in the Southern Cone. The project aims to strengthen regional capacity to manage technological innovation in response to changing demands. Financial support was provided by the Interamerican Development Bank, whose encouragement is gratefully acknowledged.

The project carried out various studies to analyze the most likely development scenarios for different production systems and to identify the problems that will need to be resolved within the agrofood and agroindustrial systems. The project also reviewed the technologies currently available for overcoming these problems. In addition, experiences in financing and reorganizing crop and livestock research worldwide were compiled and analyzed.

In order to draw lessons for future institutional change in the Southern Cone, PROCISUR invited ISNAR to undertake a study of the changes in agricultural research in developed countries. The present joint Research Report presents the study's results. The Spanish edition of this report, which focuses more on the implications for Latin America, can be obtained from PROCISUR. ISNAR and PROCISUR are pleased to make these results available to the global agricultural research community

and hope that many organizations will benefit from this report as they seek to redefine their roles and modes of operation in the opening decade of the 21st century.

The results of this study, and the conclusions of the project as a whole, will provide PROCISUR with a better basis for organizing research to develop new technology. In particular, they should lead to the identification of the multidisciplinary, interinstitutional projects that are crucial if the principal technological problems of the agriculture, livestock, and agroindustrial sectors of the Southern Cone are to be overcome. The study has helped ISNAR sharpen its ideas on the kinds of changes that are both feasible and desirable in order to enhance the contribution of agricultural research to development. We hope that other organizations in different parts of the world will also benefit from this study.

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Executive Secretary, PROCISUR

Stein W. Bie
Director General, ISNAR

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Acronyms

AFRC	Agriculture and Food Research Council (UK)
AHI	African Highlands Initiative
AROW	Agricultural Research Organizations on the Web (ISNAR)
AARINENA	Association of Agricultural Research Institutions in the Near East and North Africa
AREERA	Agricultural Research, Extension and Education Reform Act (USA)
ARS	Agricultural Research Service (USA)
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
BP	British Petroleum
BBSRC	Biotechnology and Biological Science Research Council (UK)
CARDI	Caribbean Agricultural Research and Development Institute
CATIE	Tropical Agricultural Research and Higher Education Center (Centro Agronómico Tropical de Investigación y Enseñanza) (Costa Rica)
CGIAR	Consultative Group on International Agricultural Research
CICYT	Inter-ministerial Commission for Science and Technology (Comisión Interministerial de Ciencia y Tecnología) (Spain)
CIEDUR	Inter-disciplinary Center for Development Studies
CLIMA	Cooperative Research Centre for Legumes in Mediterranean Agriculture, The University of Western Australia
CONDESAN	Consortium for the Sustainable Development of the Andean Ecoregion (Consorcio para el Desarrollo Sostenible de Ecoregión Andina)
CORAF	West and Central African Council for Agricultural Research and Development (Conseil Ouest et Centre Africain pour la Recherche et le Developpement Agricoles)
CORPOICA	Colombian Corporation for Agriculture and Livestock Research (Corporación Colombiana de Investigación Agropecuaria)
CP	Challenge Program (of the CGIAR)
CRADA	Cooperative Research and Development Agreement (USA)
CRC	Cooperative Research Centre (Australia)
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
DEFRA	Department of the Environment, Food and Rural Affairs (UK)
DLO	Agricultural Research Department (Dienst Landbouwkundig Onderzoek) (The Netherlands)
DoD	Department of Defense (USA)
DPI	Department of Primary Industries (Australia)
Embrapa	Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária) (Brazil)
ERDA	Energy Research and Development Administration (USA)
ERS	Economic Research Service (USA)
ETHZ	Swiss Federal Institute of Technology-Zurich (Eigdenössische Technische Hochschule Zürich) (Switzerland)
FiBL	Research Institute of Organic Agriculture (Forschungsinstitut für biologischen Landbau) (Switzerland)
FOA	Federal Office of Agriculture (Bundesamt für Landwirtschaft) (Switzerland)
FOES	Federal Office of Education and Science (Bundesamt für Bildung und Wissenschaft) (Switzerland)
FONTAGRO	The Regional Fund for Agricultural Technology (Fondo Regional de Tecnología Agropecuaria)

FOPET	Federal Office for Professional Education and Technology (Bundesamt für Berufsbildung und Technologie) (Switzerland)
FORAGRO	Regional Forum on Agricultural Research and Technology Development (Foro Regional de Investigación y Desarrollo Tecnológico Agropecuario)
GIPRA	Government Performance and Results Act (USA)
GDP	gross domestic product
HEFC	Higher Education Funding Council (UK)
IAMA	International Food and Agribusiness Management Association
ICIPE	International Center for Insect Physiology and Ecology
ICI	International Chemical Industries (UK)
INRA	National Institute for Agricultural Research (Institut National de la Recherche Agronomique) (France)
INSAH	Sahel Institute (Institut du Sahel) (Mali)
INTA	National Institute for Agricultural Technology (Instituto Nacional de Tecnología Agropecuaria) (Argentina)
INTSORMIL	International Sorghum and Millet Program
LNV	Ministry for Agriculture, Nature Management, and Fisheries (Ministerie van Landbouw, Natuurbeheer en Visserij) (The Netherlands)
MAFF	Ministry of Agriculture, Fisheries and Food (UK)
MDRA	Principal Division for Research and Extension (in the FOA, Switzerland)
NARS	national agricultural research system(s)
NGO	nongovernmental organization
NIH	National Institute of Health (USA)
NRLO	National Council for Agricultural Research (Nationale Raad voor Landbouwkundig Onderzoek) (The Netherlands)
NSF	National Science Foundation (USA)
OARS	Organization of Applied Research Stations
OECD	Organization for Economic Cooperation and Development
OST	Office of Science and Technology (UK)
PCCMCA	Central American Cooperative Program for Crop and Livestock Improvement (Programa Cooperativo Centroamericano de Mejoramiento de Cultivos y Animales)
PRECODEPA	Regional Project for Collaborative Potato Research (Proyecto Regional para la Investigación Colaborativa de Papa)
PROCI	Cooperative Program for Agricultural-Technological Development
PROCISUR	Cooperative Program for the Agricultural-Technological Development of the Southern Cone (Programa Cooperativo para el Desarrollo Tecnológico Agropecuario del Cono Sur)
PROFRIJOL	Collaborative Project for Bean Research (Proyecto Colaborativo de Investigación en Frijol)
R&D	research and development
RC	Research Council (Switzerland)
RDC	Research and Development Corporations (Australia)
RIRF	Rural Industry Research Funds (Australia)
SAES	State Agricultural Experiment Station (USA)
TNO	The Netherlands Organization for Applied Scientific Research
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UK	United Kingdom of Great Britain and Northern Ireland
USDA	United States Department of Agriculture
USDAFS	United States Department of Agriculture Forest Service
WFC	Wageningen Food Center (the Netherlands)
WUR	Wageningen University and Research Center
ZIL	Swiss Center for International Agriculture

Executive Summary

Public-sector agricultural research systems throughout the world today face broadly similar challenges. Globalization, market liberalization, technological advances, and evolving ideas on the role of the public and the private sectors are affecting the vast majority of countries in both the developed and the developing world. Some countries have evolved responses that may be of use to other countries, and it may be helpful to describe the institutional innovations associated with these responses. This report describes the principal innovations observed in the financing and organization of agricultural research in five countries; it also reviews the policy environment, to see how this has contributed to the reorganization of research. The study aims to inform developing countries about the most important factors that need to be taken into account when restructuring.

The need to assess research systems in depth limited the extent of the study to five industrialized countries: the USA, Australia, Switzerland, the Netherlands, and the United Kingdom of Great Britain and Northern Ireland (UK). In order to study the institutional innovations observed in the national research system, an analytical framework of three steps was applied. First, changes in the external environment were identified and classified into three groups: (1) changes in the demand for knowledge and technology; (2) changes in the ways knowledge and technology are developed; and (3) changes in the roles of the public and private sectors.

The second step describes the changes undergone by the research system in response to these external pressures. Two typical approaches to change can be observed: the first is the attempt to strengthen the existing institutional capacity, for example through improved management. This approach does not affect the organization or structure of the system, but concentrates on improving the way the system functions. The second approach is to promote institutional innovation: for example by creating new institutions or new working practices within or across institutions. In this approach, decision makers typically consider the changes needed in the research system to be beyond the internal capacity of existing institutions or, at least, that such changes will take too long to materialize if existing institutions are left to their own devices.

In step three, the observed changes in the research system are evaluated with reference to the system's efficiency and relevance. Efficiency is defined as the relationship between the results produced and the inputs required. Relevance is high if the system works on topics that major stakeholders consider to be important and if the system is working on these topics in ways that are likely to lead to a successful outcome, either in terms of making an immediate impact on livelihoods, or in terms of achieving breakthroughs in knowledge that should deliver such an impact over time. To increase relevance, new research approaches or models are often introduced.

Three categories of innovation are distinguished. First, there are changes in governance, which affect system components such as scientific councils or governing boards and involve processes such as decentralization, changes in ministerial support, and, occasionally, privatization. Second are changes in financing, such as the introduction of competitive funding, matching grants, levies, research contracts, and the functional separation between financing and implementation (where the funding government is different to the one that carries out the research). The third category describes changes in the way research is organized, for example, joint ventures between research and development, the formation of research networks, the integration of universities in the research system, and the establishment of national programs or projects that cross institutional boundaries.

Outline of analytical framework

Steps	Focus of analysis
1. Identify changes in the external environment	• Changes in demand for knowledge and technology • Changes in the ways knowledge and technology are developed • Changes in the roles of the public and private sectors
2. Describe changes undergone by organizations in response to these external factors	• Efforts for strengthening the existing capacity or for promoting innovation
3. Evaluate the effects of the changes	• Implications of the changes for efficiency and relevance

Interpretation of the experiences of individual research systems requires caution and judgment, especially if attempts are made to extrapolate these experiences to other situations. Nevertheless, the uniform analytical framework applied across the case studies helped the researchers to arrive at a useful synthesis.

Analysis of the major changes in the external environment shows that research systems face technological demands that differ greatly from those of 20 years ago. The emphasis has shifted away from primary production and toward the management of agroindustrial chains, and from productivity increases toward the improvement of food quality and safety. Developing new technologies for producers is becoming a less important public good. The challenge for research systems can be summarized as a change in identity: instead of "technology factories" they need to become "knowledge sources." In response, significant changes have taken place in research systems. The institutional innovations introduced include changes in legal status, the introduction of competition, the integration of universities, the strengthening of regulatory frameworks, and the establishment of new methods of collaboration. The impression is that research systems in the past were generally relatively efficient but not very relevant. Further changes aimed at increasing efficiency have been introduced, but these have not received the same amount of attention as institutional innovations designed to increase relevance.

It would be risky to try to draw conclusions for the developing world from the trends observed in only five developed countries. However, many developing countries face similar challenges to those described in the case studies. As a result, the study provides the following potentially useful insights:

1. It is worth asking whether the priority for a given research system should be to respond to changes in the external environment or merely to improve the efficiency of the system in delivering current outputs. When the demand for technology changes, new scientific opportunities are arising, and new ways of organizing research are emerging. Improving a system's efficiency without taking into consideration its relevance is a risky strategy, possibly even a pointless one.
2. Today's agricultural research systems are increasingly being asked to tackle problems that are, strictly speaking, external to agriculture. The emphasis is shifting away from the development of productivity increasing technologies towards that of new approaches to social and environmental issues, such as the protection of natural resources, food safety, and animal welfare. The challenge is to promote development that balances equity and environmental interests with those of economic growth, while limiting the negative external effects of agriculture.
3. In the future, public-sector research systems will be increasingly oriented toward the generation of knowledge, while the private sector assumes an ever greater role in technology generation. The growing emphasis on knowledge creation reinforces the importance of integrating universities within the research system. Sharing knowledge will create new opportunities for

transferring technologies or methods and for enhancing the dissemination of research results. It will also promote the development of a more sophisticated agricultural sector, with links to other sectors and disciplines.

4. In some countries, financial pressures on the research system have resulted in a healthier system in which new modes of operation have come into being and relevance has been considerably improved. The USA, Australia, and the UK, in particular, have seen increased emphasis on the use of competitive grants, which has led to the development of high-quality research portfolios. However, such funding mechanisms have high operational costs. Moreover, small research systems may not allow sufficient scope for real competition. Research managers should therefore analyze the pros and cons of competitive grants and other new funding mechanisms carefully before introducing them into their own systems.
5. In all the countries under study, the conduct of research by the public sector has been the subject of review. Since the "public good" argument is the rationale for the existence of public-sector research systems, it is of utmost importance to define the roles of the public and the private sector clearly. These roles vary from country to country as a function of (1) the failure of markets to produce the amount and kind of research that are in the best interests of society; (2) the need to enhance or maintain the competitive structure of markets; and (3) the existence of opportunities for exploiting the complementarity of research and education. The definition and clear assignment of responsibilities in the public and the private sectors is not an easy task, because it leaves room for interpretation and also changes over time.
6. A major trend observed in the case study countries is that agricultural research systems are opening up to include new, nontraditional players. Stronger collaboration is being sought with the private sector and with nongovernmental organizations (NGOs). The latter are playing an increasingly demonstrative part in articulating the demand for new technologies and knowledge of relevance to the poorer segments of society. Furthermore, the importance of international and regional partnerships has been recognized. At the same time, the boundaries of agricultural research systems are becoming blurred as more network-type arrangements between institutions in different sectors are taking shape. This trend is providing all who participate with access to a wider circle of experience than can be found in the agricultural sector alone, and is increasing the relevance of research outputs to a broader set of stakeholders.
7. The combination of declining political support and reduced core funding, together with the drive to make the research system more responsive to changing social needs, has resulted in a trend—most advanced in the Netherlands—toward the separation of research decision making and funding from the execution of research. Separating the two functions is seen as one of the best ways of managing a complex and pluralistic research system; it reflects efforts to enhance accountability and to respond better to the demands of an increasingly diverse group of stakeholders.

Introduction

Major processes of change in the broader social environment that surrounds national agricultural research systems are forcing corresponding changes in the structure and functions of these systems. These processes include the globalization and regionalization of markets, the liberalization of national economies, the decentralization of the state, the trend towards democracy and advances in science and technology.

To adapt to these changes, national agricultural research systems need to restructure. This study aims to inform developing countries about the most important factors that need to be taken into account when restructuring.

Objectives

Across the globe, agricultural research systems face broadly similar challenges. The vast majority of countries—whether developed or developing—are affected to some degree by the globalization of markets, economic liberalization, advances in science and technology, and new thinking about the respective roles of the public and the private sectors. Many countries have developed responses to these challenges that could be useful to other countries. Describing these responses and their effect on the research system as a whole could yield valuable generic lessons for the management of agricultural research within the developing world. The objectives of this study[1] can be summarized by the following questions:

- What global trends can be observed in the financing of agricultural research? How can the major changes that are occurring in financing be characterized?
- What financing mechanisms currently in use in developed countries provide useful points of reference for developing countries as they consider the options open to them? How have these mechanisms contributed to the reorganization and reorientation of national agricultural research systems and their principal institutions?
- What policies and strategies for financing research and technology development in agriculture, livestock, and agroindustry are pursued by the international agencies whose task is to support these sectors?
- What policies and strategies for reorganizing research institutions and systems are being pursued at the global, regional, and subregional levels?
- What experiences of reorganization are relevant to developing countries with respect to the causes and motives, the instruments used, the impact achieved, the roles of the public and the private sectors, and the factors contributing to success and failure?
- What major lessons can be drawn from these experiences for the developing world, and what are the most likely future trends in research financing and organization?

If these questions can be answered, it should prove possible to develop a set of criteria for evaluating possible changes in the financing and organization of agricultural research in developing countries. Nevertheless, it should be remembered that even the best analysis of events in other parts of the world cannot provide a formula for the future development of research systems in developing

[1] Initially it was considered that two separate studies would be prepared, one on financing and the other on organization. However, the two themes are closely related, so it makes more sense to treat them together. In fact, financing is one of the mechanisms most frequently used to change organizations.

countries. The developing world is changing rapidly according to its own laws and principles, and the diversity of natural and cultural conditions found there prevents any direct comparison.

The study analyzes developments in the research systems of the following five industrialized countries:

1. The USA, because it has the most extensive research system in the world and it is the largest exporter of agricultural products;
2. Australia, due to its relative isolation and its economic dependence on agriculture, particularly agricultural exports;
3. Switzerland, because it is a small country, isolated from large markets by its unwillingness to enter the European Union;
4. The Netherlands, because of its sophisticated agricultural sector, high productivity, and substantial agricultural exports;
5. The UK, because of the radical nature of the changes in its public sector and its role in the generation of basic scientific knowledge.

Alston et al. (1999) and Alston, Pardey, and Smith (1998) have already described and analyzed the research systems of most of these countries, and this report draws extensively on their findings. However, while their focus is particularly on financial aspects, the present report stresses the changes in the external environment and describes the institutional innovations that have occurred in response to them. In addition, the innovations are assessed against a set of criteria in order to extract new insights into the institutional change process and to make recommendations for developing countries. To take the analysis a step further, the report also presents a systematic comparison of the agricultural research systems in the five countries.

Organization of the report

The report is organized into five chapters. The introduction outlines the study and describes the objectives of the project and the organization of the report.

Chapter 1 focuses on the conceptual and methodological framework used in the study. It begins by describing the major trends in the external environment that affect national research systems. Two basic strategies for improving the functioning of research organizations are described. The methodological framework is explained using two institutional innovations as examples. Finally, the methods used to collect information are described.

Chapter 2 describes the trends and developments occurring at a global level. This includes a review of trends in research financing and organization in developed countries, and a comparison between developed and developing countries. Certain trends are reviewed in relation to cooperative research between countries, international research, and the policies of development agencies.

The majority of chapter 3 concentrates on analyzing trends over the past two decades in Australia, the USA, the Netherlands, the UK, and Switzerland. For each of these countries, the research system, trends in public- and private-sector financing, changes in the external environment, and noteworthy institutional innovations that have arisen in response to these changes are described. An evaluation of the innovations is then made as a function of the criteria for assessing relevance, explained in chapter 1, and the probable future development of each system is discussed.

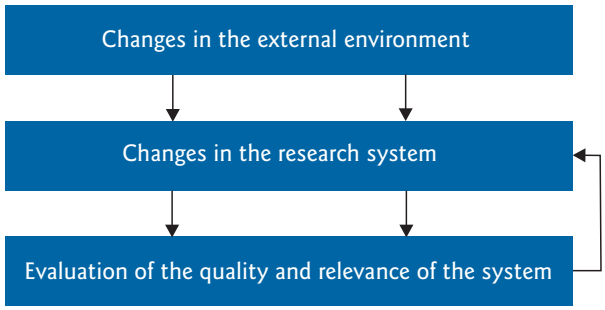
Chapter 4 summarizes and synthesizes the analysis presented in the previous chapters and draws general conclusions and lessons that can be learned across the case studies.

Chapter 1. Conceptual and Methodological Framework

In order to interpret the changes observed in research organization and financing, we use a simple analytical framework consisting of three steps. The first step defines the major changes occurring in the external environment and classifies them into three groups: (1) changes in the demand for technology and knowledge; (2) changes in the means of generating knowledge and technology; and (3) changes in the roles of the public and the private sectors. Changes in the external environment have a major effect on research systems, compelling them to redefine their objectives and responsibilities.

The second step analyzes the different ways in which research systems have been modified in response to changes in the external environment and highlights the conditions under which specific innovations (or change strategies) may be most effective. Three types of innovation or internal change in research systems are distinguished: (1) changes in the governance or guidance of research systems, including organizational elements such as scientific councils and governing boards, and processes such as decentralization and privatization; (2) changes in financing e.g., greater use of competitive grants, shared funds, levies, and research contracts, and the separation of research financing and research implementation; (3) changes in research implementation models e.g., joint ventures, research networks, integration of universities into research systems, and multi-institutional programs.

The third step uses a literature review as a basis for setting criteria for evaluating the quality of research systems, especially their relevance. These criteria include: (1) separation of financing and implementation; (2) pluralistic structure e.g., joint ventures and research networks; (3) focus on public goods; (4) complementarity between public and private sectors; (5) autonomy of the different system components; (6) stakeholder participation; (7) capacity for technology transfer; and (8) presence of adequate legal frameworks. These criteria allow conclusions to be reached regarding the overall impact of changes in the structure and functioning of the research systems. Figure 1.1 provides a summary of the conceptual framework employed.



Note: The arrows indicate the direction of causality between the different steps.

Figure 1.1: Conceptual framework for describing trends in the financing and organization of agricultural research

The conceptual framework is illustrated in section 1.4 by the examples of regionalization within the country and competitive funds, two institutional innovations that have been under consideration in many countries. Table 1.1 in section 1.4 provides an evaluation of these two innovations. The example clarifies the means by which the conceptual framework is applied, allowing others to establish additional criteria or to understand where particular judgements may differ from ours.

Relatively few countries have developed a holistic vision of the desirable structure of their research system and gone on to implement this vision in a single, comprehensive package of changes. For political reasons, individual problems or principles associated with external changes are more often identified and acted on consecutively, leading to a continuous process of piecemeal reform.

Over 20 or so years, the "traditional" research system is thus gradually reconfigured into a newer or more modern system in response to various theories, political pressures, interests, emerging needs and opportunities. The result is a hybrid—a compromise between different influences—whose structure tends to reflect the dominant ideas of the time or the dominant powers in the land. It is the consequence of an evolutionary process, not of a coherent, one-off design. And as such it tends to be relatively unstable: systems are increasingly subject to a process of continuous re-engineering as they attempt to respond to the ever quickening pace of change in the world about them.

1.1 External trends affecting the development of agricultural research systems

Agricultural research systems generate knowledge and technology to promote agricultural development in general and to contribute specific benefits to specific interest groups. The relevance of these research systems can be analyzed in the context of a simplified framework of supply and demand for research services (figure 1.2). The framework reflects (1) changes in the demand for technology and knowledge, either as explicitly expressed by farmers or as implicit in the political objectives established for agricultural development; (2) the use of new and advanced tools and processes for generating and disseminating knowledge and technology; and (3) the prevailing philosophy regarding the roles of the public and private sectors in general. How these roles are changing in response to structural adjustment, for example, is an important factor to consider when analyzing the external environment.

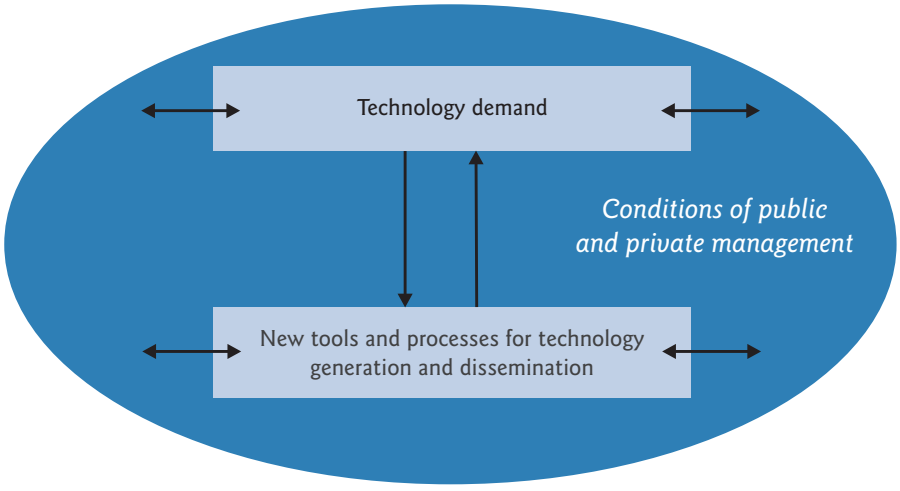


Figure 1.2: Three important factors in the external environment of research systems

1.1.1 Changes in the demand for technologies and knowledge

The demand for technologies and knowledge is changing, because society in general and the agricultural sector in particular are changing. Factors such as rising incomes, urbanization, environmental degradation, and market liberalization have stimulated the demand for better stewardship of natural resources and for increased access to growing consumer markets. The kind of production technology needed by farmers is also changing, as new inputs and approaches, such as disease-resistant seeds and integrated pest management, become available. The quality standards that new technologies must meet are increasingly defined at the international level, since farmers' products must compete in international markets and with imports in domestic markets. ISNAR (1998) has more detailed information on changes related to the demand for technologies and knowledge in Latin America.

1.1.2 Changes in research tools and processes

A second group of changes relates to the implications of recent advances in research, leading to the use of new tools and processes. These advances are gradually breaking down the traditional frontiers between disciplines and sectors. This trend is most apparent in the field of biotechnology: for example, a molecular biologist may work in a hospital or in an agricultural research laboratory. New tools and processes such as gene mapping have cross-sectoral benefits but are expensive to develop, depending more on collaborative work between different institutions than on teams drawn from a single institution. The international exchange of scientific information has advanced greatly as a result of improved communications and reduced travel costs—a factor that has encouraged institutions to access and apply research results from others, rather than starting afresh themselves. Another significant development is the increase in the number and extent of intellectual property rights in the form of patents or authors' rights. Piñeiro (1999) provides a more detailed analysis of the challenges and opportunities arising from advances in science and technology.

1.1.3 Ideas about the roles of the public and the private sectors

National agricultural research systems (NARS) in developing countries are predominantly publicly funded and managed and as such will be subject to the pressures for reform exerted on the public sector as a whole. The public sector is often criticized for its lack of efficiency and cost control. It is argued that, to control budgets and reduce inefficient spending, the public sector should concentrate only on those functions that are not well executed by the private sector. However, deciding just what these functions should be requires judgements that are not always easy to make. For some functions (such as justice, police, and defense) the role that government should play is self-evident, but for others it will vary from country to country, depending on specific conditions.

During the past 20 years, concerns have arisen over the role and management of NARS in a number of countries. Agricultural research can be managed by the public sector yet funded by producers, particularly if the latter are well organized and there is consensus regarding the taxes or other instruments that help to finance the research. If the government considers that a product has strategic value or plays a socially desirable role in agricultural development (e.g., in terms of poverty alleviation or environmental conservation), it can decide to provide additional financing. The comparative advantage of public-sector agricultural research is that it can benefit resource-poor farmers who are of little or no interest to the commercial sector.

1.1.4 Economic transformations

The task of understanding the effect of changes in the external environment on agricultural research is complicated by a factor that has not received much attention in this study but that is nevertheless of great importance due to its implications for developing countries. While most developing countries have a sizeable agricultural economy, the agricultural sector is of far less economic importance in developed countries, where it is nevertheless highly organized and uses sophisticated technology. By definition, the developing countries face different economic and technological conditions and will therefore need to respond to global changes in different ways.

1.2 The need for and nature of institutional change

Most agricultural research systems of the developing world are subject to criticism from stakeholders, who feel that that their major technological needs are not being met and that the methods used by researchers are out of date. A further criticism is that the responsibilities of the public and the private sectors are not adequately defined and that the public sector does not focus on the right priorities and target its resources effectively. In these cases, it is important to develop responses that can increase the relevance, or effectiveness, of the system.

Two typical responses to these criticisms can be expected: decision maker is to try to strengthen the system's existing institutions, for example by means of improved management. This strategy does not usually alter the organization or structure of the system, or at least not in major ways; instead it concentrates on improving the functions that the system performs within the existing structure. It attempts to improve such activities as priority setting, planning, monitoring, evaluation, information management, and financial and personnel management. This strategy tends to be used when decision makers are confident of the capacity of existing institutions to regenerate and evolve.

The second response is to change the structure of the system by creating new institutions (e.g., by merging institutions or by reorganizing or redefining them) and/or new working methods. This response is based on the assumption that traditional institutions either do not have adequate resources (human, financial, or physical) to meet the new challenges posed by the external environment or are insufficiently flexible to adapt to these challenges. In other words, decision makers believe that the required changes are either wholly beyond the capacity of existing institutions or that they will not materialize fast enough if these institutions are merely left to their own devices. This institutional-innovation strategy is often attractive to policymakers, who frequently find it difficult to assess whether an institution is sufficiently flexible to respond to new challenges.

The internal changes observed in the research systems of the case study countries tend to be a mixture of these two typical responses. In other words, elements of change directed at improving the functioning of existing institutions tend to be combined with more radical institutional innovations. The strategy of strengthening existing institutions tends to be associated with gradual internal change, which is often found to be acceptable within the system. The institutional innovation strategy, in contrast, is more radical—and more risky: if well planned and implemented, it can bring about a real and long-lasting improvement in the system, but if badly designed or implemented, it may have devastating effects. To guide our thinking in this respect, the two dimensions that need to be evaluated are the efficiency and the effectiveness, or relevance, of the research system.

1. **Efficiency** is defined as the relationship between the results produced and the inputs required. If a high level of inputs is required to produce few results, then the efficiency of the system is low; if few inputs are required but results are plentiful, then efficiency is high.
2. **Relevance** refers to the system's response to external developments. The three challenges mentioned earlier orient the interpretation of relevance:

- *Changes in the demand for technology:* themes such as agroindustrial development, the degradation of natural resources, and food safety are altering the agricultural research agenda in many countries.
- *Changes in research tools and processes:* exporting countries that are technological pioneers in certain product areas need to develop sophisticated research facilities and programs to maintain their competitive position. This requires a broad and strong scientific base in these product areas. Given the high degree of specialization and the high costs associated with many new research techniques (those of biotechnology, for example), it is difficult to see how a single institution could develop all the required capacity over a large number of research topics. The need to focus, whether on priority commodities or on certain key problems, will therefore increase.
- *Changes in the roles and responsibilities of public-sector research:* countries that are undergoing major public-sector restructuring and reorganization will also have to establish new mechanisms for accountability and guidance in their agricultural research systems and consider transferring services that can be performed more efficiently by the private sector.

A system that produces relevant results but lacks efficiency can be a major cause of dissatisfaction, both internally and among external stakeholders such as farmers and policymakers. The priority is then to seek greater efficiency through better performance of essential functions such as planning and financial and personnel management. In this situation, it would be unnecessary and risky to change the structure and organization of the system, since this might achieve greater efficiency but could also decrease relevance.

On the other hand, if the research system functions efficiently but does not appear very relevant, the priority for institutional change will be to redirect its focus toward the most important problems and to ensure it tackles these problems in ways conducive to a successful outcome. Institutional innovations directed towards this end might be implemented rather easily as the system is already operating efficiently.

If the research system has little relevance because it has failed to adapt adequately to the changes in its external environment, its right to exist may be questioned, even if it functions efficiently. Since the external environment is changing rapidly, it may be desirable to respond by establishing new institutions or new mechanisms for guidance, financing, or collaboration.

Figure 1.3 illustrates (in a simplified form) these different change strategies. In reality, there are of course degrees of efficiency and relevance, rather than two extremes.

Condition of the national research system		**Internal efficiency**	
		Low	High
External relevance	Low	Develop institutional innovations independent of the existing system	Develop institutional innovations within the research system
	High	Improve the functioning of the existing institutions with emphasis on public responsibility	Continual improvement of management in existing institutions with emphasis on research support

Figure 1.3: Viability of strategies for institutional change or improved management

Certain developed countries have introduced a substantial number of institutional innovations in their national research systems over the past decade.[1] It appears that the majority of these innovations have been intended to improve system relevance. Normally these innovations have been imposed on the system by national governments, or by governments working in agreement with beneficiaries, in an attempt to redefine the role of the system.

Regarding the future development of agricultural research systems, both in developed and in developing countries, the need to maintain relevance should be the prime factor motivating discussions and innovations. Instead of increasing results per unit of input, research systems should seek to ensure that they produce useful results around relevant themes.

1.3 Criteria for evaluating system quality and effectiveness

Byerlee and Alex (1998) define seven criteria that, according to their analysis, characterize relevant and efficient NARS that contribute effectively to agricultural development. All these criteria are related, in one way or another, to the aforementioned challenges:

1. **Separation between financing and implementation of research:** it is considered that the establishment of priorities and the allocation of funds are political concerns, whereas the implementation of research is principally a question of efficiency and technical quality. It is therefore the responsibility of research providers to implement research with greater efficiency, in accordance with priorities established outside the system.
2. **Pluralist structure:** in pluralist NARS, researchers from different institutes pool their expertise to maximize progress and avoid duplication of effort.
3. **Focus on public goods and diversification of financing:** the government has certain functions that cannot be transferred to the private sector, such as the provision of public funds for basic and strategic research and for research into problems related to small-scale agriculture and natural resource management. The application of this criterion depends a great deal on the level of development of the agricultural sector. Applied research can only be left in the hands of producers' organizations when these are well established, as they are, for example, in Australia (see section 3.1.1).
4. **Complementarity between the public and private sectors:** the efficiency of the research system can be increased by sharing capabilities and resources and working on shared objectives.
5. **Institutional autonomy for public-sector research organizations:** autonomy increases flexibility and responsibility within the system and tends to promote activities oriented toward concrete results, as well as a more professional administration of human, financial, and physical resources.
6. **The participation of stakeholders in defining the research agenda:** the many options for achieving this participation range from inviting stakeholders to take part in planning meetings or to sit on the governing boards of research institutions, through the financing of research wholly or in part by farmers and other clients, to contractual arrangements for the implementation of research by its principal intended beneficiaries.
7. **New models for technology transfer:** these need to reflect changes in the structure of the agricultural sector, such as the integration of production chains and the decentralization of natural-resource-management policy making and implementation. They also need to incorporate the opportunities created by developments in information and communications sciences. Farmer participation is the key characteristic of many of the new models.

Piñeiro (1999) emphasizes four pillars for establishing an effective NARS: (1) define priority themes that correspond to development objectives, are compatible with the scientific capacity of the country, and provide opportunities for inter-institutional collaboration; (2) seek means of research

[1] These observations are illustrated in greater detail in Chapter 4.

financing and implementation that reinforce the complementarity between the public and the private sectors; (3) invest in the scientific capacity of the country to conduct applied and adaptive research; (4) strengthen legislation regarding property rights to enhance access to innovations generated in other countries.

The criteria set by Piñeiro are compatible with those set by Byerlee and Alex, in terms of the focus on public goods and complementarity between the public and the private sectors; Piñeiro's concept of scientific capacity and Byerlee and Alex's pluralistic structure are also similar. However, the legal framework regarding property rights, indicated by Piñeiro, has not been taken into account by Byerlee and Alex and should be added to their list of criteria (becoming criterion number eight in our list).

At present, many research systems are concerned with finding the right balance between public-sector and private-sector activities; between funds assigned to special projects and nonspecific funds; between academic liberty and the commitment to research beneficiaries; and between conducting exploratory research without concrete goals and fulfilling downstream responsibilities towards research users. Finding this balance is a difficult task, but one that appears easier to meet in a multi-organizational research system than when research is the responsibility of a single organization.

These criteria have influenced institutional innovations in many research systems. Successful innovations should combine elements that enhance both relevance and efficiency. However, ex ante evaluation of the likely effects on relevance and efficiency of specific innovations is almost always subjective. Even ex post evaluation is complicated by the political nature of the change process, which may affect the outcome independently of the kind of innovation introduced. A review of the effects of institutional innovations already introduced in other countries can nevertheless help predict what may happen in the national system and will at least highlight some of the potential advantages and disadvantages.

1.4 Options for institutional innovation

During the 1990s, institutional innovations of various kinds have been introduced in agricultural research systems in both developed and developing countries. These innovations can be categorized as belonging in three fields: (1) research guidance and direction, (2) financing, and (3) management and implementation. Innovations within these fields can be combined, and indeed it may be necessary to combine them if they are to be really effective.

In the area of guidance and direction, some of the more noteworthy innovations include separating policy making and implementation; decentralizing research; transferring research from ministries of agriculture to ministries of science and technology; involving farmers and other stakeholders in research planning and evaluation; providing partial or complete autonomy to research institutions; and privatizing research.

Noteworthy innovations in financing include the introduction of competitive mechanisms for allocating funds, grant matching, endowment funds, surcharges, and research contracts. Separating the funding of research from that of implementation has also been tried (for more details see Janssen 1998).

In management and implementation, the following innovations have been noted: the establishment of international research chains, joint R&D enterprises, or research centers between the public and private sectors, the integration of universities and NARS, the consolidation of fragmented research systems, the use of public-sector funds to conduct private-sector research, and a multi-institutional approach to research.

A deeper analysis of developments within NARS would reveal many other institutional innovations, and the range of options continues to increase as new experiences accumulate. How options are chosen within a specific context depends on the goals of the institution, and the choices are conditioned by the NARS' institutional culture.

In this study, two examples of institutional innovation were analyzed in relation to Byerlee and Alex's criteria in order to characterize the effectiveness of the NARS: decentralization and introduction of competitive funding.

1.4.1 Decentralizing agricultural research

Many developing countries are involved in decentralizing research decision making and implementation to the regional level, with greater involvement of the end-users of new technologies in the planning and implementation phases. This approach also places greater emphasis on natural resource management, as environmental problems tend to appear more significant at the local or regional level. An increasing emphasis on adaptive research, aided by improved communications, is also encouraging decentralization.

One of the benefits of decentralization is the establishment of autonomous regional research centers (or councils) that can target their resources to regional or local priorities. To be effective, regional research must come under a clearly defined governmental structure that allows for the participation of different stakeholder groups. For example, decentralization requires a different approach to planning commodity research—one in which local, rather than national, interests determine plant-breeding objectives. It also requires the development of a national coordination and guidance system. Another key to success in decentralized research is that regions should be delineated by a combination of agroecological, socioeconomic, and administrative boundaries.

Decentralization or regionalization is most suited to countries where regions can be clearly identified by their socioeconomic and agroecological characteristics. This tends to occur in countries with a large surface area. Relatively small countries (for example, Benin, which is implementing a regionalized agricultural research system), however, can also follow regionalization strategies.

According to Byerlee and Alex's criteria, the effects of decentralization on NARS can be characterized as follows:

- Decentralization does not necessarily lead to the separation of research funding and implementation (criterion 1). Within regions, the number of institutes that supply research tends to be lower than at national level and, as a result, funding and implementation are often more closely related.
- Decentralization can lead to the diversification and strengthening of research throughout the entire country. It therefore stimulates pluralism in the NARS (criterion 2). However, regional research can lead to duplication, particularly where there is little contact between regions or where regions are distinguished from one another by administrative rather than agroecological boundaries.
- Decentralization does not necessarily contribute to a greater focus on public goods (criterion 3). In some cases, the role of the public sector in adaptive regional research is less evident than in basic or strategic research. Decentralization can lead to the diversification of funding sources by improving interaction with local agricultural communities and establishing new fund-raising mechanisms.
- Interaction between the public and the private sectors (criterion 4) tends to be easier to promote at a regional level. If public-sector research is client-oriented and adaptive, producers will be keen to share responsibilities for planning and implementing it. Also, if industrial interests are identified at a regional level, links will be easier to make between public research and industry.

- Decentralization generally leads to increased autonomy in research systems (criterion 5), because producers play a stronger role in guiding the research process. However, if autonomy is not supported by decision makers, decentralization may be ineffective, leading to frustration.
- Decentralization contributes substantially to the participation of stakeholders in research design, guidance, and management (criterion 6). In fact, it is often initiated with this purpose in mind.
- Decentralization also contributes to the development of new mechanisms for technology transfer and promotes the participation of producers in adaptive and applied research (criterion 7). It means that researchers will live in the producers' environment, improving their perceptions of how best to interact with clients.
- Decentralization may not contribute to the protection of research results in terms of intellectual property rights (criterion 8). With less central control and direction, it is more likely that intellectual property rights will unknowingly be violated.

1.4.2 Competitive funding

In a competitive funding approach, institutions are invited to prepare research proposals according to previously determined rules and norms. The "best" proposals are selected and financed. Normally, the responsibility for managing competitive funds is given to a small office or organization (Janssen 1998). Competitive funds tend to provide a flexible way of allocating resources, permitting the research agenda to be readily adjusted to meet new demands. They emphasize the recipients' responsibilities for the resources allocated and for the effectiveness of the research. Frequently, collaboration is imposed as a condition for financing, with the expectation that this will improve effectiveness.

The viability of competitive funding as a mechanism depends on having a large enough number of research providers to allow real competition. Clear policies regarding the balance between fixed and variable research costs are needed. If there are no stable sources of financing, research institutions that lose competitive bids can find themselves without funds and therefore unable to survive. Normally, funds are allocated for a period of three years or less, and continuity is not guaranteed. Competitive funds require evaluation and approval systems that are neutral and strict with respect to both personnel and procedures. The management and administration of competitive funds can be costly (Echeverría 1998), but, under the right conditions, they definitely contribute to improving the quality of research.

Competitive funds can be analyzed as follows (according to Byerlee and Alex's criteria):

- Competitive funds have been shown to be most effective in separating research financing and implementation (criterion 1), and this is one of the principal reasons for establishing this type of financing.
- With respect to the diversification of research within institutions, competitive funds strengthen the pluralistic character of research systems (criterion 2). However, they may reduce pluralism if they lead to the demise of uncompetitive institutions.
- Competitive funds generally have clear criteria for financing initiatives in the public and private sectors and sometimes focus specifically on public goods (criterion 3).
- These funds can contribute to strengthening the interaction between the public and private sectors (criterion 4) through the establishment of conditions that specify collaboration.
- Research institutions with full or partial autonomy (criterion 5) are not normally affected legally by competitive-grant programs. Nevertheless, their autonomy may in fact be prejudiced by the need to compete for funding.

- Stakeholders such as farmers and policymakers can become involved in competitive-grant programs (criterion 6), but more often these tend to be managed by former researchers and government functionaries.
- Competitive-grant funding applications may ask for information about mechanisms for the transfer of technology but when awarded, the funds rarely contribute to an improvement in this function (criterion 7). In the majority of cases, the mechanisms for technology transfer are organized centrally, tending to increase the perceptual gap between researchers and users.
- Competitive funds do not contribute to the establishment of a better intellectual property rights system (criterion 8). Although conditions are often imposed about who can access results, competitive funds may create confusion about ownership, since there is a question over whether patents belong to the financing agency or to the researchers.

Table 1.1 summarizes the evaluation of the two innovations discussed. The objectives of the two innovations are very different and not necessarily compatible, giving rise to important questions. For example, are some criteria likely to be more important than others in a given external environment? Can a compromise be reached when conflicting innovations are introduced? How can the undesirable effects of an innovation be mitigated? These questions all have a bearing on the anticipated impact on the relevance and efficiency of the NARS.

Table 1.1: Evaluation of Two Institutional Innovations Based on Eight Criteria for Characterizing Effective NARS

Criteria[1]	Regionalization within countries	Competitive funds
1. Separation of financing and implementation	–	+
2. Pluralist structure	±	+
3. Focus on public goods	–	+
4. Complementarity between public and private sectors	+	±
5. Institutional autonomy	+	±
6. Stakeholder involvement	+	–
7. Effective transfer of technology	+	–
8. Positive and clear legal structure	±	–

[1] The criteria are from Byerlee and Alex (1998) and Piñeiro (1999).

\+ = affected positively by the innovation
± = affected neither positively nor negatively by the innovation
– = affected negatively by the innovation

1.5 Information collection

The development of research systems in specific developed countries, with particular reference to the systems' financial aspects, is described in Alston et al. (1999), Alston, Pardey, and Smith (1998), and Huffman and Evenson (1993). There are also many articles on this subject in professional journals (for example, *World Development*). ISNAR's library has a very large collection of gray literature on this topic. These information sources constitute the basis for this study.

Three sources of complementary information have been used:

1. Data up to 1993 was drawn from the Agricultural Research Indicator Series available at ISNAR.
2. Extensive use was made of the Internet. Agricultural Research Organizations on the Web (AROW) at www.isnar.cgiar.org/arow, a website developed and maintained by ISNAR, was consulted on many occasions. AROW allows access to information on the most recent developments in the selected countries.
3. Experts familiar with the research system in the selected countries were consulted. In the USA, the Netherlands, the UK, and Switzerland, recognized experts were asked to prepare articles on major change processes, following the methodological framework presented in Chapter 1 (Huffman 1999; Meer 1999; Roberts 1999; Baur and Rieder 1999). In Australia, a national expert was consulted during his stay at ISNAR (Henzell, personal communication). The articles emphasize institutional innovations within the different countries, the causes of the different outcomes, and their consequences for the effectiveness of the research systems. When this information is combined with the quantitative data taken from the other sources, it is possible to synthesize experiences and spell out the possible implications for developing countries.

Chapter 2. Global Trends and Developments

Over the past two decades, agricultural commodity markets have become increasingly globalized. So too have markets for the technologies developed by agricultural research. Consequently, new strategies for organizing and financing research in developing countries cannot be conceived in isolation, but must reflect developments in other parts of the world. This chapter analyzes global developments by

- outlining the principal trends in the research systems of developed countries. These trends are described in further detail for five selected countries in chapter 3;
- comparing trends in developed and developing countries in order to understand the most important differences;
- briefly describing developments in the international agricultural research system of the Consultative Group on International Agricultural Research (CGIAR);
- examining the performance of regional organizations and their implications for developing countries.

2.1 Financing and organization of research systems in developed countries[1]

National public spending on agricultural research in developed countries varies considerably. In general, the level of support reflects the size of the country's agricultural sector. The largest budgets for agricultural research are found in the USA, Japan, France, Canada, the UK, Italy, Germany, Australia, and the Netherlands (Pardey et al. 1999).

Spending on private-sector agricultural research is greatest in the USA, Japan, the UK, France, and Germany, mainly thanks to the various multinational conglomerates that have their headquarters in these countries. The figures suggest that private- and public-sector research complement rather than substitute for one another. Countries that have traditionally provided substantial support for public-sector research have created a good environment for research and technology development, which motivates the private sector to advance its own research.

According to Alston, Pardey, and Smith (1998), between 1981 and 1993 private-sector research expenditures grew by 5.1% per year while public-sector research expenditures grew by only 1.8%. Private-sector agricultural research grew faster than private-sector research as a whole, while investment in public-sector agricultural research fell faster than that in public-sector research as a whole. The growth in aggregate agricultural research (public and private sector) continues at a rate of approximately 3.4% per year, slightly lower than the 4% growth rate in total research.

Support for agricultural research is channeled mainly through ministries of agriculture or of science and technology. The following general trends can be identified in the majority of agricultural research systems:

1. **Mandate:** there appears to be a decrease in the importance of traditional agricultural research oriented toward productivity, and an increase in research on socially relevant themes such as environment and food safety. It is likely that, in developing countries, the relative importance

[1] This section presents information provided by the Regional Fund for Agricultural Technology (FONTAGRO) (Janssen and Herruzo 1999).

of research oriented toward productivity is greater than in Europe. Nevertheless, it seems that a similar (although less pronounced) change is also occurring in many developing countries.

2. **Coordination and formulation of agricultural research policy:** this is now less frequently formulated in agricultural research institutions and is increasingly becoming the responsibility of government ministries or of science and technology councils. In addition, agricultural research policy is increasingly being integrated into general science policy. When agricultural research institutions operate as commercial suppliers of research, for example under contract, they are likely to develop a strong client focus, moving close to the goals defined by their clients. Indeed, some institutions are implementing active commercial strategies in order to attain these goals. If the institutions' legal frameworks permit, their client base may consist of a great variety of participants, including government ministries, regional and local government entities, industries, and farmers' associations. This development is not welcomed in all circles. For example, in the case of the USA, Huffman and Just (1999) argue that researchers' commercial activities tend to reduce their creativity and their willingness to undertake basic research.
3. **Structure and organization:** over the past decade, the structure and organization of agricultural research have been subject to an increasingly rapid rate of change. This reflects new ideas about interactions between the public and private sectors, such as the client focus described earlier (Persley 1998). Some of the most rapid changes have occurred in the UK, where the government has sharply reduced its support for agricultural research. In other countries, such as the Netherlands, the government is abandoning institutional financing but still finances a substantial research program through contracts with old research organizations that now function almost as private sector entities. Privatization is not the only means of improving control over, and client responsiveness in, agricultural research. In France, there is a sophisticated mechanism for exercising control that ensures that research carried out by the national agricultural research institute and by regional organizations responds to the needs of farmers (Roturier 1998). Innovative research methods are being established that combine public and private sector research, for example in the Wageningen Food Center in the Netherlands. It should also be noted that scientific capacity is well maintained in the majority of the countries studied—for example in the USA, Germany, and Sweden—thanks to the important role played by their universities.
4. **Financing:** depending on the political context, another common point is the clear separation between program financing and implementation, with a trend towards increasing separation. Increasingly, researchers are having to develop and present projects that correspond to criteria imposed by financing entities, or that satisfy contractual arrangements with specific clients. The uncertainty related to the new financing methods tends to favor universities, their educational mandate giving them a strong and stable base.
5. **Legal protection of intellectual rights:** the private sector invests in agricultural research purely to make a profit. A legal framework that adequately protects intellectual property rights is therefore very important. Ginarte and Park (1997) distinguish five interacting factors that determine the effectiveness of patents awarded in any country: (1) the scientific fields in which a patent can be obtained; (2) international treaties that guarantee the respect for patents awarded in other countries and vice versa; (3) the ability to maintain an obsolete patent; (4) the ability to sanction patent violations; and (5) the duration of patent protection.

2.2 Trends in organization and financing in developing countries

It is more difficult to obtain reliable information on trends in research financing and organization for developing than for developed countries. In addition, the figures cannot be interpreted with as much clarity due to high rates of inflation, problems with definitions of categories, and different public accounting systems. Since 1992–93, developments in these research systems have been very dynamic. Information for some developing countries has been collected and this reveals some inter-

esting facts (table 2.1). First, the research intensity ratio—agricultural research spending as a share of agricultural gross domestic product (GDP)—tends to be lower in developing countries than in developed countries. There are exceptions, such as Brazil, Kenya, and Zimbabwe, but these are cancelled out by countries such as Ecuador, China, and others, which have ratios that are far lower still. Countries that derive a large percentage of their GDP from the agricultural sector have greater difficulties in distributing public expenditures proportionately, since other sectors that have to develop rapidly require high investments. This explains why developing countries generally have lower research intensity ratios than developed countries. Whereas they are at around 2.1% of GDP in the latter group, they average 0.3% in Latin America, 0.3% in Africa, 0.5% in China, 0.3% in Southeast Asia, and 0.6% in South Asia (UNESCO 1998).

Table 2.1: Public and Private Expenditures on Agricultural Research in Selected Developing Countries and in General, 1992

Country	Public expenditure on agr. research (PuE) (US$millions 1985)	Intensity ratio PuE/GDPAg[1] (%)	University percentage	Private expenditure on agr. research (PvE) (US$millions 1985)
Argentina	83.0	0.76	5	7.8
Brazil	790.6	1.56	22	18.3
Chile	37.9	0.98	20	1.6
Colombia	47.7	0.45	2	27.1
Ecuador	10.0	0.27	5	6.9
Mexico	143.1	0.58	17	52.6
Peru	29.0	0.99	20	3.9
Venezuela	46.9	0.73	10	4.6
India	1561.8	0.52	33	493.2
Zimbabwe	20.3	1.88	n.d.	8.7
Kenya	33.3	1.76	n.d.	5.9
All devel'ing countries	**8009**	**0.50**	**n.d.**	**n.d.**

Sources: Cremers and Roseboom (1998); Echeverría et al. (1996); Beynon et al. (1998); Pray and Deininger (1998); Tabor et al. (1998)

[1] GDP of the agricultural sector

The second interesting factor is related to the participation of universities in agricultural research. In developed countries, an average of 43% of agricultural research spending goes to universities, but this does not occur in developing countries, where research and education tend to be separated.

The third interesting phenomenon is the participation of the private sector. Private-sector research investments appear to be limited in developing countries (except India), and agricultural research funding depends almost exclusively on the public sector. In developed countries, both sectors participate almost equally. This leads to another conclusion: growth in public agricultural research funding in developing countries over the past 20 years has been more rapid than in developed countries. This means that developing countries have been able to reduce the gap and, today, public research investments are very similar. Developed countries have the advantage of being able to mobilize scientific personnel in the private sector, where research spending grew at 5.1% per year between 1981 and 1993.

Although the 1990s brought public-sector structural reforms to many developing countries (Tabor 1998), changes in agricultural research mandates and functions have not been as pronounced as in the developed countries. As table 2.1 suggests, the institutional structure of the research systems in developing countries is not very diversified, and the potential of the private sector is yet to be realized. The slow rate of change appears to be related largely to the lack of established public institutions in developing countries (Janssen and Wilks 1999; Rahman 1999). Developing countries also tend to lack effective stakeholder organizations that are capable of accepting part of the responsibility for effective agricultural research.

The most noteworthy changes in research organization and financing within developing countries have occurred in Latin America (Echeverría et al. 1996). Chile is often mentioned as an example of new financing mechanisms (competitive funds). Uruguay is recognized for financial sharing between producers and the government. Brazil has experienced less change in terms of its institutional structure, but certain institutes—specifically the Brazilian Agricultural Research Corporation (Embrapa)—have experienced a great deal of change. The developments in Mexico with the Produce Foundations (producers' entities in charge of allocating research resources), or in Colombia with the establishment of the Colombian Corporation for Agriculture and Livestock Research (CORPOICA) under private laws, are some of the most pronounced changes implemented in developing countries. The majority of the modifications have been made principally in response to changes in ideas about public and private sector responsibilities and have been induced by budgetary problems. The changes are not related to new technological demands or to new opportunities in the organization and implementation of science.

Many challenges for the progress of research systems in developing countries remain because they have not yet begun to reorient their systems. Nevertheless, reorganization should be dealt with carefully, because errors have a high cost. On the other hand, change is important, not only to improve theoretical effectiveness, but also to keep the research system active and aware. No recipe can determine the adequate rate and intensity of change, since this depends strongly on each country's specific conditions.

2.3 Trends in organization and financing of international research

The most important entity involved in international agricultural research is the CGIAR, a network of 16 international research institutes. Other independent international research centers include the Tropical Agricultural Research and Higher Education Center (CATIE) for Central America, the Caribbean Agricultural Research and Development Institute (CARDI) for the Caribbean, the Sahel Institute (INSAH) for the Sahelian countries, and the International Center for Insect Physiology and Ecology (ICIPE), based in Nairobi, for entomological research. Collaboration mechanisms also exist between countries, such as the Cooperative Program for the Agricultural Technological Development of the Southern Cone (PROCISUR) for the Southern Cone of Latin America, but these are, in general, less developed. The first efforts are also being made to establish competitive regional mechanisms (FONTAGRO 1997). Here the information is focused on the CGIAR, which is the largest component of the international research system.[2]

Over the past seven years, the CGIAR has experienced satisfactory financial growth (table 2.2). However, financing sources have changed considerably, with greater emphasis being placed on European donors and less on North American ones.

[2] Nevertheless, the CGIAR budget is less than that of Embrapa, for example.

Table 2.2: CGIAR Financing and Principal Research Objectives, 1993, 1996, and 1998

	1993	1996	1998
Total financing (US$ millions)	235	304	340
From Europe (%)	35	43	44
From North America (%)	24	15	15
From international organizations (%)	24	21	19
Used to:			
- increase agricultural productivity (%)	48	40	37
- protect the environment (%)	14	16	19
- conserve biodiversity (%)	6	11	11
- improve agricultural policies (%)	10	12	12
- reinforce NARS (%)	22	21	21

Source: CGIAR 1999

Behind these figures lie many changes in the organization and financing of the CGIAR. Table 2.3 summarizes four of the most important ones. First, the CGIAR has tried to increase its focus on topics related to natural resource management and poverty reduction. As can be seen in table 2.2, the allocation of resources to environmental protection and biodiversity conservation grew by 20-30%. These changes correspond partly to the perceptions of the European donors about the main limitations of agricultural development in developing countries. Second, the CGIAR has been receiving less unconditional funding and more restricted funding for certain projects, probably because donors feel the need to show how their financing contributes to agricultural development. Third, the CGIAR has made a great effort to increase the number of partners and increase the influence of developing countries in the system. The system has 43 member countries, of which 19 are developing and transition countries. The fourth change is the development of a broader and more representative guidance system through regional and world forums that were established with the support of the CGIAR. The forums include representatives of the private sector, non-government organizations (NGOs), advanced research institutes, NARS, and other organizations interested in agricultural research in the different countries. Together, they define the major goals for agricultural research in the region and share courses of action and interests.

More recently, the CGIAR launched an initiative to design and manage change. This far-reaching program of reform will affect its governance, programs, science, management, and potential impact. The four pillars of the program are: (1) a small Executive Council to conduct business between annual meetings; (2) a Science Council to ensure that the science practiced by the centers continues to meet the highest international standards for quality and relevance; (3) a Systems Office to bring cohesion through an integrated communication, public awareness, and fundraising strategy; and (4) Challenge Programs that respond directly to major concerns on the global development agenda.

The formulation and implementation of Challenge Programs (CPs) is a major change for the CGIAR, with important implications for the research operation of individual centers. Over time, these programs will induce structural change among the centers. CPs are designed to expand the CGIAR's current pool of partners and to mobilize new and increased funding from current and prospective donors. They will help increase the impact, significance, and visibility of the CGIAR's research efforts by better aligning its research toward achieving the millennium development goals and opening up the CGIAR to broader partnerships. The interim Science Council has recommended three CP proposals for full development: global genetic resources, water and agriculture, and harnessing agricultural technology to improve the health of the poor.

Table 2.3: Effects of Four Changes within the CGIAR With Respect to Effectiveness Criteria

Criteria	Attention to natural resources and poverty reduction	Restricted project funds	Increase in the number of partners	Regional and world forums
Separation between financing and implementation		+		–
Pluralist structure				+
Focus on public goods	+			
Public-private complementarity	+			+
Institutional autonomy		–		
Stakeholder participation			+	+
New models for transfer of technology				
Clear and positive legal structure				

Note: Own judgements. Only positive (+) or negative (–) effects are indicated.

2.4 Developments in regional agricultural research organizations

Regional collaboration is one way of dealing with problems that affect more than one country (Walton 1994). Different countries in a region are often faced with similar agricultural problems because they share the same climatic and edaphic conditions. Putting resources together for joint research can help the region resolve its problems. The effectiveness of regional initiatives depends on how easy it is to define common problems, strategies, and coordination methods, and whether efficient and equitable cost-sharing mechanisms can be found. The costs of regional collaboration have decreased over the past decade due to the great progress in communication technology.

Regional collaboration brings additional advantages to research. Knowledge can be shared and transferred in a more efficient manner, and research on new topics can be initiated while avoiding unnecessary costs or risks for each country. Regional mechanisms can increase political influence at the world level and can also help to integrate different countries' scientific systems, as is the case with the European Union. Donors are interested in regional mechanisms, since these permit the donors to finance several countries through one initiative (Gijsbers and Contant 1996).

Eponou (1998) distinguishes several different types of regional collaboration. These are summarized, with certain additions, in table 2.4.

Table 2.4: Types of Regional Collaboration in Agriculture

Type of collaboration	Activities	Benefits	Risks	Examples
Regional consortia	Multidisciplinary and multi-institutional projects	Broad participation, focus on specific problems	Weak commitments between partners, lack of identity	CONDESAN, AHI
Regional collaboration organizations	Various programs shared between partners	Solid programs, regional presence	Mobilization of partners' resources, coordination costs, political process	PROCIs
Regional institutions	Generation of technologies, training	High quality, sustainable programs	Low regional identification	CATIE, CARDI, INSAH
Regional associations	Exchange of experiences and results	Mutual support and problem recognition	Political influence, lack of research	ASARECA, AARINENA, CORAF
Regional forums	Exchange of information on problems	Open character, contacts	Lack of commitment	FORAGRO
Regional networks	Exchange of information, generation of technologies	Solid program and directed exchange	Distance from national problems, low political support	INTSORMIL, PROFRIJOL, PRECODEPA
Professional associations	Disciplinary exchange	Disciplinary contacts	Lack of sustainability	PCCMCA

Source: Eponou 1998 and own additions.

The types of organizations described in table 2.4 show a decreasing trend for the intensity and size of the collaboration from top to bottom: consortia require much greater management and coordination than do professional associations. Trends observed in regional cooperation in the 1990s include:

1. Consolidation: the multitude of small-scale regional collaboration initiatives is being consolidated under more general organizations. For example, the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA).
2. Broadening partnerships: traditionally, networks and other collaboration initiatives were formed by homogeneous organizations (NARS-type), and partner homogeneity was considered to be an important factor in their success (Plucknett et al. 1990). There is now a tendency to recognize the importance of a broader collaborative base even if this complicates the work. Two relatively new forms of collaboration illustrate this point: (1) consortia, which bring together quite diverse partners around a common problem and which attempt to jointly define research and development strategies; (2) forums, which imply less commitment in terms of actions, but which provide a means for exchange between many participants and which can lead to collaborative actions between groups.
3. There is a less clear trend toward sharing problems rather than sharing an interest or a discipline. Consortia provide a clear example of regional cooperation mechanisms with a problem-oriented (e.g., agroecological) focus. The advantages of a problem-oriented focus are that it permits the definition of partners' objectives, goals, and responsibilities, which in turn permits better management and evaluation of the collaborative effort. The disadvantage is that the reason for collaboration ends the moment that the problem ceases to need attention.
4. Partners may be unwilling to share results if they are working on topics that affect their relative competitiveness. If a country exports a product to other countries in the same region, it

probably will not want to collaborate in research centered around this product. Similarly, if one country dominates the world market, it will not want to share its results with neighbors who are possible competitors. However, this difficulty will not arise when partners satisfy a small part of the international demand for a certain product. The solution is to emphasize action-related to problems or topics that do not affect competitiveness, and to focus on partner countries' internal conditions (for example, natural or genetic resources), or to work on precompetitive topics (basic research). In other words, regional research has a greater chance of success if the results permit each partner to benefit without other partners being hurt.

5. The majority of regional collaboration initiatives depend largely on nonnational resources, often provided by donors, and there has been little progress in finding internal sources of funding (Perrault 2001). Efforts to pass financial responsibilities to the partners have met with little success, with the exception of a few cases such as PROCISUR. Willingness to pay the costs of regional collaboration is only evident where there is a political concern with regional integration. This is the case with the European Community's regional research collaboration, which is seen primarily as an instrument to create sustainable links between scientific communities in different countries.
6. In the final analysis, the strength of regional collaboration is defined largely by the strength, relevance, and strategies of the partners. If partners lose relevance within their national environments, regional initiatives will naturally lose their relevance. In addition, if the partners have open partnership strategies that expose them to other perspectives or experiences, the regional initiative is likely to come under pressure to act in a similar manner. In a world characterized by open alliances, three strategies are likely to extend the coverage of regional research mechanisms:
   (a) Seek a gradual increase in the number of partners at a rate that permits the identity and objectives of the regional organization to be maintained. The question here is: will nontraditional partners be interested in linking with an organization based on the concerns of others, and do they feel the need for, or see a benefit in, establishing this link? With respect to traditional partners, the question is: do they see a benefit in being affiliated with a regional organization and does it compensate them for the loss of their individual influence?
   (b) Seek alliances with other regional organizations that represent nontraditional partners in order to broach topics of common interest. This approach has the advantage of maintaining the regional organization's identity. The disadvantage is that it becomes difficult to define actions or concrete projects as there will be two levels of negotiation: between and within regional organizations. This strategy's viability increases if the nontraditional partners have a high degree of organization. For example, the International Food and Agribusiness Management Association (IAMA) has regional sections that can be approached by regional agricultural research organizations to identify topics of common interest.
   (c) Broaden the partnership base by integrating other types of organizations and emphasizing a problem-oriented focus (a development toward the "consortium" model). The advantage of this strategy is that it permits collaboration between different types of partners to be organized around a problem. The disadvantage is that the regional organization can no longer identify itself with a certain type of partner. This approach becomes more viable if there is a strong sponsor for the consortium and if there is little regional organization between nontraditional partners.

Chapter 3. Trends in Selected Countries

Trends in research systems in different developed countries can be best understood through in-depth studies. This limited the number of countries that could be included in this study; five countries have therefore been selected to give a more precise idea of the principal developments. The case studies are presented in this chapter.

The five selected countries are Australia, the USA, the Netherlands, the UK, and Switzerland. There are many lessons to be drawn from these countries that are important for the development of national research systems in developing countries. The countries selected represent great variability in size, market access, levels and directions of agricultural research, and relevant government policies, which reduces the possibility for "tunnel vision" that arises from excessive emphasis on one country. The reasons for selecting these countries are summarized in table 3.1.

Table 3.1: Basic Characteristics of the Case Study Countries

Country	Characteristics
Australia	Agricultural economy of intermediate size with an extensive resource base, export oriented, distant from markets, with few subsidies or other political supports for the agricultural sector.
USA	Very large agricultural economy with an extensive resource base, very competitive on internal and external markets, with intermediate levels of support for the agricultural sector and with the largest and the most advanced agricultural research system in the world.
Netherlands	Agricultural economy of intermediate size, based on a very intensive use of resources, very competitive in European markets with high levels of support for the agricultural sector but with diminishing public-opinion support. Member of the European Community.
UK	Intermediate to large agricultural economy, intermediate in terms of the intensity of resource use, with intermediate competitiveness and high support levels, and a trend toward public support for "organic" agriculture. Member of the European Community and leader in the process of public sector adjustment.
Switzerland	Small agricultural economy, intermediate with respect to resource use, low competitiveness of the primary sector and high agroindustrial sector competitiveness, with limited markets due to nonmembership in the European Community and political support and orientation toward resource conservation.

The analysis presented here is not exhaustive. To understand all of the developments in these complex research systems would require extensive documentation of each case, so that analysis might tend to be lost in description. It is expected that the most important developments can be extrapolated by applying the conceptual framework laid out in chapter 1.

3.1 Australia

Australia is a very large country—it is both a continent and an island with a total surface area of 7.7 million km^2. It has a relatively small population with 18 million inhabitants. Per capita income is around US$ 18,000 per year (World Bank, 1998). Unlike the other countries in this study, Australia is

in the southern hemisphere. It is a long way from industrial centers and traditional consumer markets in North America and Europe. It is also a long way from the Japanese market, but close to the Asian countries bordering the Pacific that have undergone a very significant process of development over the last few decades. Australia is organized as a federation of seven states.

Much of Australia has a semi-arid climate that limits the viability of certain types of agriculture. Australia's competitive advantages in the agricultural sector have been developed by means of extensive agriculture and technical advances that permit agriculture despite limited water availability. Australia has been very effective in exporting certain products such as wool, beef, cotton, wheat and, more recently, wine. Australia is one of the five leading agricultural exporters in the world and export markets are a major goal for the agricultural sector. Achieving this goal is complicated by the enormous distances separating the country from many markets. The primary agricultural sector contributes 3% of GDP and employs nearly 6% of the work force (World Bank 1998), suggesting that agricultural incomes are substantially lower than average incomes.

3.1.1 Description of the research system

In 1993, the Australian research system was supported by a US$ 315 million budget[1] (Aus$ 505 million), and its public expenditures were very high in relative terms, expressing the importance the country attributes to agricultural research as a competitive instrument. Public investment expenditures are close to 4% of GDP. The public agricultural research system in Australia has developed around three institutions (Mullen et al. 1996):

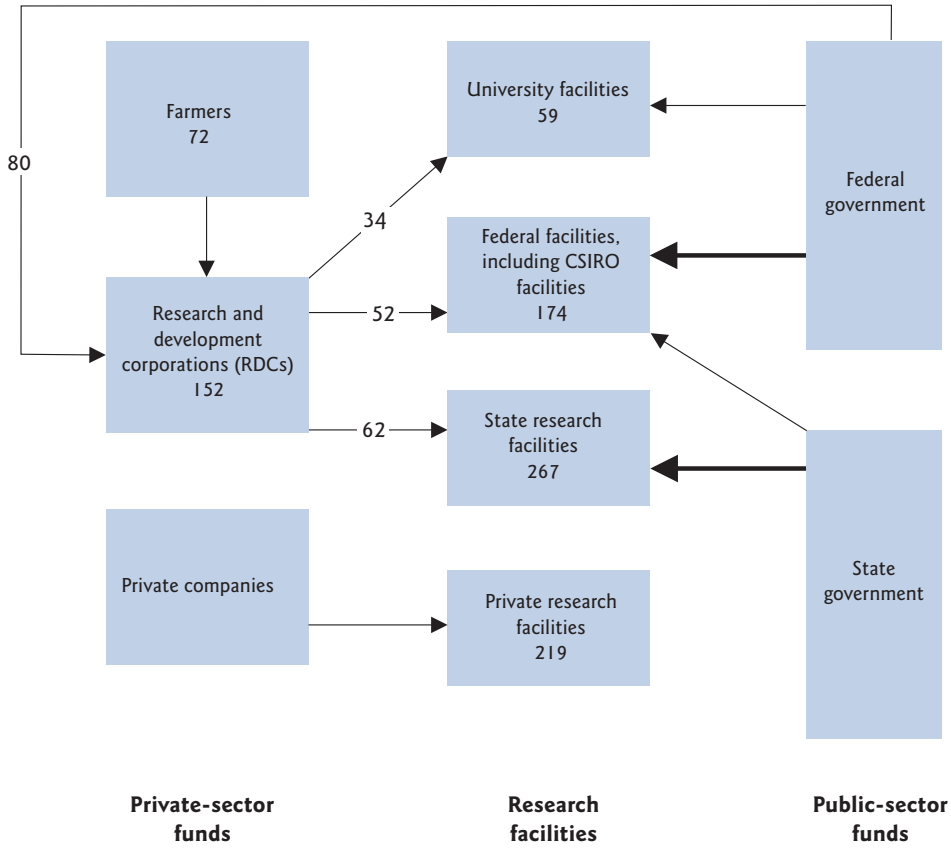
1. The **state departments of agriculture**, which manage research centers (54% of total expenditure), traditionally focus on applied themes that are of direct relevance to the government. The departments generally have responsibility for extension and regulation as well as for research. At the beginning of the 1990s, the growth of funding in the departments was slightly negative (-0.6% per year).
2. The **Commonwealth Scientific and Industrial Research Organization** (CSIRO), with 34% of total expenditure, manages research themes at the federal level. This organization works in many areas, and only 20% of its research is centered on agriculture. Traditionally, CSIRO concentrated on basic scientific research, which was used by the state departments. Due to financial pressures (30% of its funds had to be generated from nongovernmental sources), CSIRO began to develop applied research programs. Between 1990 and 1994, it achieved a positive growth rate of 6.6% per year in funding.
3. **University research systems** account for 12% of total public expenditures. There are 10 universities that have agricultural research programs (Mullen et al. 1996), and these receive the majority of their financing from federal sources. Research funds are concentrated on basic and strategic topics, and grew by 5.1% per year between 1990-1994.

There is a moderate level of private research in Australia. In 1994 it represented 43% of public investment. Private research was mainly concerned with the food industry and experienced very rapid growth, estimated by Alston et al. (1999) at 15% per year between 1982 and 1993.

Public research in Australia is highly dispersed. In 1989, there were 493 research units with an average of 11 researchers each (Henzell et.al. 1998). In order to change its orientation, the Australian system has suffered from excessive reforms and institutional reorganization. It is also worth noting that, although emphasis is given to applied research, growth in the public sector is greater in institutions involved in basic and strategic research. Currently, there is a move to merge state department research with that done by universities, for example in Tasmania (personal communication with E. Henzell). Efforts are also being made to establish links with private enterprise, with the goal

[1] US$ in 1985.

of reinforcing national capacity in new areas such as biotechnology. Figure 3.1 summarizes the structure of the Australian system.



Note: 1 AUS$ (1993)= 0.61 US$ (1985)

Figure 3.1: Principal funding flows for rural research in Australia, 1993 (millions of AUS$)

Public agricultural research financing comes from three main sources. The most important source in terms of influence is the body of Research and Development Corporations (RDCs). The RDCs finance between 30 and 40% of public agricultural research in Australia. The remainder comes from the federal and state governments. Exact figures cannot be ascertained, but the majority of CSIRO's financing comes from the federal government, and the majority of financing for the state departments comes from the state governments. It is also worth noting that state-government budgets are largely provided by the federal government.

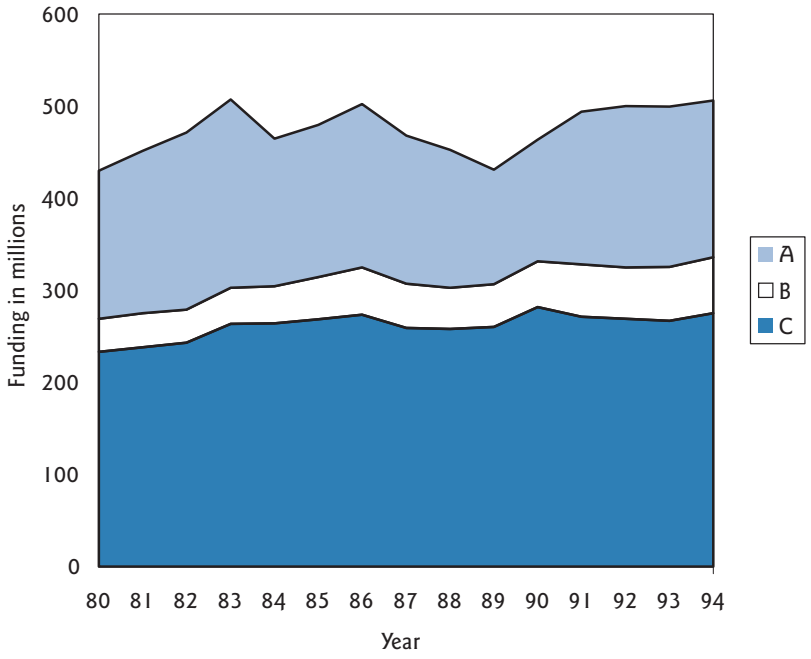
Decisions about research orientation are made partly within the institutes, particularly in the state departments, where the separation between state financing and execution is not very clear. However, a large number of decisions are made within the RDCs. In 1997, there were 14 RDCs organized around producer groups (Lovett 1997). The RDCs are governed and managed by producer representatives and their financing is derived from a sales tax surcharge set by the federal government at a maximum of 0.5%. Producers therefore have a large influence on the financing and guidance of the Australian research system. In fact, financing through the RDCs largely defines the orientation of the system.

The Australian system has been characterized by research that aims for international market competitiveness despite having a relatively narrow technological base. With relatively low levels of public expenditure (the USA spends seven times more on agricultural research) strong guidance for the use of resources is needed to prevent the benefits of research getting lost. The search for competitiveness is further complicated by the low level of private-sector involvement. Private investments in agricultural research total less than half those of public investment. By comparison, in the Netherlands, where public research expenditure is lower than in Australia, private research expenditure is double.

The Australian system has not paid much attention to the environment; first, because a large proportion of the funds is controlled by RDCs,and second because there are few environmental problems in a large country where natural resources are not over-exploited.

3.1.2 Trends in public and private financing

Figure 3.2 shows that there has been slight growth in Australian public system funding between 1980 and 1994, although there have been large fluctuations around this trend. The fluctuations correspond partly to economic problems occurring in the country and in the public sector, and associated difficulties in maintaining public financing for agricultural research. In the mid-1980s, a double concern with agricultural research financing arose. Firstly, financing did not translate into a productive and relevant research system able to export results and increase agricultural-sector competitiveness. Secondly, political support for agricultural research was weakening due to the decreasing economic importance of the primary sector.



A: Expenditures on CSIRO
B: Expenditures on universities
C: Expenditures on state departments
Source: Mullen et al. (1996)

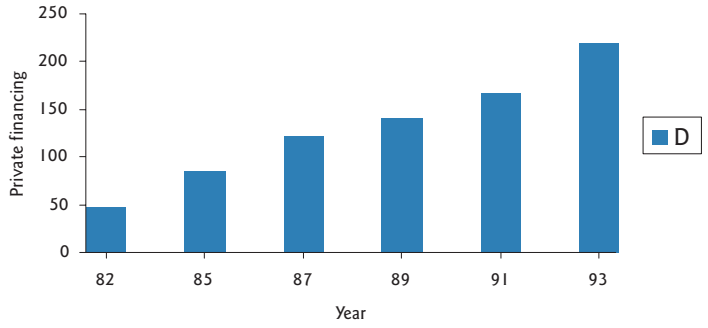
Figure 3.2: Public agricultural research financing in Australia, 1980–94 (millions of constant AUS$ 1985–93)

Between 1985 and 1991, a model of governance for research was introduced through producer councils managed out of the Department of Primary Industries (DPI). This was replaced in 1991 by a corporate model. The two models were able to increase the availability of research funds for the sector. The final result was a growth rate of 1.3% in real terms, which increased the public agricultural research intensity ratio by around 0.4% per year. Taking into account the fact that Australian producers are confronting declining prices in the world market and that the costs of research per researcher have increased, Mullen et al. (1996) came to the conclusion that research efforts, in relation to the physical quantity of production, have reduced considerably.

Public-system funding can be separated into state departments, universities, and CSIRO (figure 3.2). The greatest financial development over the period 1980–94 was in the universities, whose budgets grew in real terms by almost 4% per year. The position of the state departments was strengthened in the 1980s, but was weakened in the 1990s, with an overall growth rate of 1% annually. State departments fared better under the council system, when there was a stronger link between system governance and the DPI, than under the corporate system, which has reduced the link between the DPI and research system. CSIRO had the inverse experience. Its financing decreased in the 1980s and began to increase in the 1990s. Overall, its growth rate was nearly equal to that of the departments.

The different growth rates over the period of analysis suggest that, when research service demand and supply are separated, demand focuses on the best educated and qualified suppliers, who generally concentrate on the most basic topics (universities and CSIRO). At the same time, in response to this demand, these suppliers became reoriented toward applied topics. Analysis carried out by the Australian Bureau of Statistics confirms this trend (cited in Alston et al. 1999). This could be related to the difficulties associated with establishing adequate prices for research services. It could also be true that CSIRO and the universities reaped the advantages of a more independent position.

Figure 3.3 presents the growth in private research expenditures over the years under study. Between 1982 and 1993, the growth rate is estimated at 14.8% per year, which is much higher than the growth rate observed in public research expenditures. Without doubt, the private sector has



D: AUS$millions (1993)

Source: Alston et al. (1999)

Figure 3.3: Private agricultural research financing in Australia, 1993 (millions of constant AUS$ - 1993)

been the most dynamic component of the Australian system. On the other hand, this growth began from a low initial base, and the participation of the private sector in the research system continues to be limited in comparison with the other countries selected for study.

3.1.3 Changes in the research context

Technological demands. The Australian system has been under strong pressure to perform, since prices for its primary agricultural products have declined and new international markets for manufactured products cannot be found. Competitiveness is, without doubt, the most important goal for the Australian system.

Since the end of the 1970s, the Australian government has markedly reduced agricultural-sector protection, placing additional demands on the research system to find technological advances. Existing interventions, such as input subsidies, support for investments in irrigation, transport subsidies, and price policies, were all abolished. At the beginning of the 1990s, the degree of support for primary production in Australia was estimated at only 25% that of other developed countries (OECD 1995). In many parts of the agricultural sector, support through research and extension has been the principal form of government assistance (Alston et al. 1999).

Pressure on natural resources has not been seen as a problem in Australia, and environmental demands have not been channeled through the research system. Henzell et al. (1998) suggest that this may change in the future, since they consider that long-term sustainability and the acceptability of Australian agricultural products will depend on good environmental management.

Changes in the organization of science and research. Australia is located on the fringe of the developed world with respect to advances in the field of biotechnology. Its public research system lacks sufficient capacity to exercise leadership in this area and there are no sufficiently large multinationals in the private sector capable of developing their own biotechnology programs (Henzell, personal communication). An important objective for the Australian system is to establish alliances with foreign private enterprises, which would permit access to and use of biotechnology. However, at present, the research system is highly dispersed and the emphasis is on applied research. These two factors tend to compromise the ability of the country to achieve greater biotechnology capacity.

Legislation related to intellectual property rights is somewhat less advanced in Australia than in the other countries studied (Ginarte and Park 1997), and does not contribute to private companies' interest in undertaking research in Australia.

The feasibility of broadening the scientific base depends, then, on the following factors: (1) the concentration of sufficient resources around concrete initiatives; (2) the integration of external knowledge within these initiatives; and (3) the creation of incentives for private industry participation. The Cooperative Research Centres (CRCs) respond to this problem, and are described in section 3.1.5.

Public and private responsibilities. There has been a substantial debate in Australia about public and private responsibilities, partly for budgetary reasons that became evident in the mid-1970s. Therefore, attempts have been made to reduce the role of the government in various respects. As discussed earlier, the reduction of government interventions in the agricultural sector was one of the consequences. While the involvement of the government in agricultural research was largely accepted because of the market failure argument (i.e., individual farmers cannot raise the required funds for effective research), the debate started to change the thinking on public and private responsibilities.

Another important influence on the agricultural research system appeared in the 1990s. The central point was that, in an open world market, the research has almost no effect on consumer prices. The majority of its effects are passed to producers in the form of reduced costs. Since producers are well-organized through the RDCs and can finance their own research, the question then became, why does the government contribute more to the generation of technology in the agricultural sector in comparison with other sectors? Proposals were made to reduce the contribution of the government to the RDCs and to increase the autonomy of the research departments (Australia Industry Commis-

sion, 1995). Simultaneously, it was suggested that public finance should concentrate on public research (basic research, environment, and consumer protection). Following a lively debate, the Industry Commission assumed the following position:

- Producers' financial responsibility should increase since they are the principal beneficiaries.
- Agricultural research also has many benefits that are not for producers.[2]
- It is difficult to make a precise separation between research as a public good and as a private good due to practical elements in research organization.
- There are reasons to maintain research in the state departments and to maintain integration with extension and regulatory functions.

The debate was accompanied by a discussion about the management of public funds. In general, the impression was that research units' management was insufficient, and had the effect of reducing researchers' initiative. The system of accountability was also underdeveloped, and much research was carried out on the basis of implicit government subsidies (for example, only operational costs, and not personnel costs, were charged). It appears to be difficult to resolve these problems as long as there is a strict relation between departments and state government. With these subsidies, it is likely that external financing (for example for the RDCs) will have a disproportionate effect on the system's priorities.

3.1.4 Responses and institutional innovations

Governance. The greatest change occurring over the past 20 years in the Australian system has been the establishment of mechanisms that give greater influence to producers. At first, the Research Councils coordinated from DPI, together with producers, defined research topics that were contracted with the research units through competitive funds. The Councils were later transformed into fully autonomous RDCs that had funds available from production surcharges and government matching funds. The RDCs are described in greater detail in section 3.1.5.

The influence of the research users increased with the development of the RDCs, implying a certain decentralization of the system. The RDCs have also contributed to establishing more formal mechanisms for research project evaluation, and they certainly have improved research management in Australia. There were no major trends toward privatization or greater autonomy in the research units.

Financing. With the establishment of the RDCs, Australia has put greater emphasis on matching funds. The RDCs control a fund provided by surcharges and government donations and apply this fund to their research and development priorities through competitive mechanisms or contracts. The RDC mechanism, in fact, combines four forms of alternative financing: matching funds, competitive funds, surcharges, and contracts.

In the Australian system, financing has not been completely separated from execution. This separation exists within the RDCs since they do not implement research. The RDCs have many contracts with the state departments, but the Treasury subsidizes these departments. This indicates a subsidy for, and a silent approval of, the RDC-initiated research programs, preventing complete separation between funding and implementation. This means that the "tail" (the RDCs) "wags the dog" (the departments), resulting in a criticism from the producers, who say that the departments have too much influence through the RDCs (Robertson, cited in Henzell et.al. 1998).

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[2] It is surprising that it does not determine who are the others that benefit from agricultural research. At least four groups can be distinguished in many cases: the government itself, agroindustry, producers, and scientists. Also, consumers and environmental groups can be considered as beneficiaries. If only farmers are identified as beneficiaries, the public may quickly arrive at the opinion that they should cover their own research costs.

Research implementation. The CRCs have produced great changes in Australia. They attempt to combine institutions and disciplines and to develop teams with a sufficient critical mass to address important problems.

A second change in Australia has been the establishment, in 1982, of the Australian Centre for International Agricultural Research (ACIAR), which leads Australian agricultural research collaboration with other countries. Through the ACIAR, Australia manages its interactions with the CGIAR system and with agricultural research in African and Asian countries.

The increasing budgets of universities indicate that their role in the Australian research system is growing. Efforts are also being made to unite state research departments with universities, as is the case in the states of South Australia and Tasmania. These initiatives approximate the US Land Grant model.

Finally, it appears that the implementation of research through private institutes is increasing by means of competitive funds and contracts from RDCs, but on the basis of public funds (Henzell et.al. 1998; Lovett 1997). There is no data that would permit an analysis of the magnitude of this development.

3.1.5 Noteworthy initiatives

Research and Development Corporations. The RDCs were established at the beginning of the 1990s to share research financing and management between producers and the public sector. Fourteen RDCs cover all principal agricultural products, as well as fisheries and forestry products. The RDCs are financed through Rural Industry Research Funds (RIRFs), which have been in existence for most products since the 1960s, but in the case of sugar, for nearly 100 years. The RIRFs obtain their funds through obligatory surcharges on the sale of agricultural products.

The essential characteristics of the RDCs are: (1) the subsector is clearly defined; (2) half of the budget is financed through a surcharge and the other half through a subsidized government matching fund; (3) the board of directors is independent and competent; (4) clear objectives and priorities are defined; (5) research programs are negotiated with implementing institutions around the defined objectives; (6) the focus is on subsectoral problems, and projects that have usable results are prioritized (Smith 1992).

In 1965, the RIRFs financed around 20% of all public agricultural investment, but their importance diminished over the subsequent 20 years. The basic reason for this was that the subsectors didn't participate in research management and considered that interests within the research system determined the use of these funds. Certain changes contributed to the revitalization of financing in the RDCs:

- the selection of managers based on knowledge and experience rather than political criteria;
- the preparation of five-year research plans in consultation with industry;
- greater demand for auditing and public responsibility;
- corporations' employment of professional teams instead of government assigned personnel;
- the government promise to match industry contributions with public funds;
- the independence of the RDCs with respect to the federal government.

At present, the RDCs finance more than 30% of all public research. They do not have their own research infrastructure but contract out research with the CSIRO, the universities, and the state departments. Their freedom to contract out research or call for competition means they can demand higher research quality and better planning and evaluation mechanisms.

The RDCs are relatively small organizations. In 1999–2000 the cereals RDC managed a budget of some US$ 68 million and its website showed that it had a 25-person team. Its governing board consisted of three producers (including the President), a representative of the food industry, three scientists, one member of the federal government, and one management expert. Six board members are named by the government in accordance with the recommendations of the Federation of Grain Producers, and the other three are named directly by the government.

According to the recommendations of the Industrial Commission (1995), the financial formulae for the RDC should change. Instead of 50:50 financing up to a total of 1% of the value of production, the new proposal is to finance (between the government and surcharges) equal parts up to a total of 0.5% of the value of production, where the government will contribute the rest at one dollar for every two dollars received by the subsector. The 1% ceiling will be eliminated. According to Alston et al. (1999), these recommendations have yet to be accepted by the government.

Cooperative Research Centres. The CRCs were established in 1991 to create the required critical mass to maintain Australia at the forefront of international technological progress. The idea has been tried in other countries, especially in the area of engineering. In the CRCs, researchers from the public and the private sector are linked with users, mainly from the agricultural sector. The CRCs require the participation of a university and also bring together people from different institutions for a limited period of time (seven years, in general), to attempt to resolve technological problems in a multidisciplinary fashion. The CRCs also act as a platform for advanced training at postgraduate level. Another purpose is to improve the interaction between the public and the private sectors.

The CRCs were established by the Federal Government to cover many areas, both inside and outside agriculture. In 1997, 65 CRCs received a total of Aus$ 146 million. There were 15 CRCs in agricultural research and another seven in natural resource management, both of which received public financing of up to US$ 1.4 million per year. Additional contributions can be forthcoming with the condition that they are relatively proportionate to government spending. At present, for each public dollar spent, two dollars are received from other sources. The contributions from CRC partners are often in the form of personnel and equipment. Nevertheless, it can be questioned whether the size of the CRCs really represents a critical mass in the scientific world.

The CRCs are financed through competitive funds for a limited period of time (seven years). The competition is managed by the Federal Government's Department of Industry, Science, and Technology. The CRCs receive financing only if they satisfy strict conditions. Many applications to form CRCs have been rejected because of a lack of scientific or socio-economic merit. The CRCs contribute to a change of attitude in the scientific system from a position of curiosity to one of problem solving, and from one based on an institutional perspective to one based on cooperation.

The integration of agricultural research into the general scientific system. This is another important characteristic of the CRCs. One of the largest agricultural research providers is CSIRO, which manages more than 30% of public expenditure on agricultural research. CSIRO is active in many other sectors so that its agricultural efforts constitute only 20% of its total program. The CRCs were established by the Department of Industry, Science, and Technology both for agriculture and for other sectors. Of the 65 CRCs that existed in 1997, only one third were concerned with the agricultural sector or with natural resources. Universities that wish to play an important role within the CRC system do not concentrate only on agriculture, but have a wide range of research interests.

3.1.6 Conclusions

A large proportion of Australian agricultural research is oriented toward applied themes, and this gives rise to questions about its public nature. The argument is that agricultural research (for example, for the wool sector) does not have a larger public component than research oriented toward

improving mining technologies or communications systems. The problem of market failure has been resolved by the establishment of the RIRFs and the RDCs. It has been proposed that the cofinancing regime of the RDCs should be changed to become similar to the tax regime related to investment and research in the manufacturing industry. The debate has not yet been concluded and is centered on the ways in which agricultural research affects society in comparison with other sectors. Nevertheless, the mere fact that the debate exists indicates that attitudes toward the agricultural sector are changing.

At present, control of the agricultural research system in Australia rests with producers through the RDCs. This is an excellent system, because it creates commitment to research from one of the most important stakeholder groups. Nevertheless, this approach can lead to various problems. One of these is that the needs of other beneficiary groups are ignored. Over-dependency on agricultural producers also risks losing the political support of other stakeholder groups. The second problem is the provision of a double incentive for producers to finance their own research. The first incentive is provided through matching funds and the second through the supply of research services to the RDCs at subsidized prices. The double subsidy could have been justified by the abolition of the other subsidies to the agricultural sector at the beginning of the 1970s. However, as time passes, the memory of this justification will diminish. It is difficult to predict what will happen in the future, but it is likely that when a new government takes power, there will be less political support for agriculture.

A third element of note in the Australian system is the importance that the agricultural producer has as the principal stakeholder in the research system and in agricultural production. Little attention is focused on the overall agri-supply chains, and they appear not to have been integrated into the new Australian system designs. It can be observed that

- the dynamics of the agricultural sector worldwide are propelled largely by input and post-harvest industries;
- Australia is concerned with the difficulty of entering markets for manufactured products and by the decreases in prices for its primary products.

The conclusion is that, with the present strategy, the Australian system is likely to achieve a reduction in agricultural production costs, but may not achieve a more competitive position in world markets.

Table 3.2 summarizes the most noteworthy changes in the Australian system over the past 20 years. The RDCs have had a very positive effect on system functioning. They permit the separation of financing and execution, contribute to the development of a pluralist structure, and facilitate the forging of links between the private and the public sectors. In addition, they have constituted a very effective mechanism for integrating the management of the system. They have not had a positive effect with respect to the focus on public goods, as the RDCs are inclined toward the interests of the producers.

The CRCs create a critical mass through open cooperation that stimulates a pluralist structure. They also create competition with the nonagricultural scientific sector, and the expectation is that this should contribute to enhanced research quality. They permit collaboration and sharing of objectives between the private and public sectors and thereby establish a new model for knowledge and technology transfer. The doubt about the CRCs is whether their volume of operation is sufficiently large to meet their goals.

Table 3.2: Noteworthy Changes in the Australian Agricultural Research System over the Past 20 Years

Criteria	RDC	CRC	General integration
Separation between financing and implementation	+		
Pluralist structure	+	+	+
Focus on public goods	–		
Public-private complementarity	+	+	+
Institutional autonomy			
Stakeholder participation	+		–
New technology transfer models		+	
Clear and positive legal structure			

Source: Developed by the authors.

Integration with other scientific sectors was a government- rather than a DPI-initiated action, but the DPI and its associated research organizations have reacted successfully and with enthusiasm. Although this integration does not contribute to greater stakeholder participation, it does have positive effects in terms of the pluralist structure of the system and in terms of the possibility to interact with research suppliers in other fields. In a country with limited scientific resources, collaboration between different sectors is a very promising strategy toward obtaining maximum impact with the funds invested.

3.2 The USA

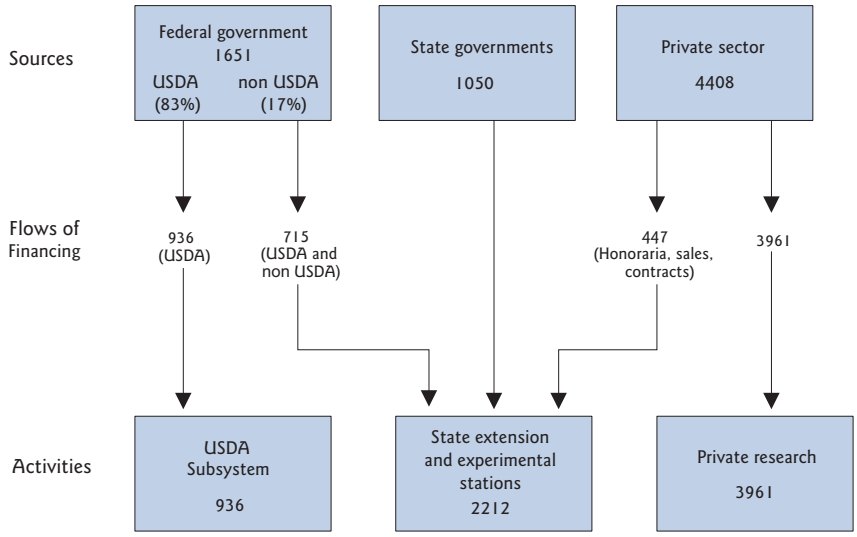
The USA is a huge country, with a total land area of 9.3 million km^2, a population of 261 million, and a per capita income of US$ 26,000 in 1994 (World Bank, 1998). It is bordered by two oceans and has one of the most important rivers in the world, the Mississippi, which facilitates water transport of many products. The USA is a federation of 50 states. The federal government is responsible for national affairs (the most obvious example is defense policy), whereas states have responsibility for local affairs. Over the past 15 years, the importance of the federal government has reduced.

The USA has a range of diverse climates and soils, many of which support productive and large-scale agriculture. It has used a sophisticated scientific research system to convert this comparative advantage into competitive advantage. In particular, its basic grain production (wheat, maize, and soy) is impressive, and it also maintains very strong positions in many other products (beef, milk, cotton, citrus, and fruit). It is the world's largest exporter of agricultural products, and it has the most productive agricultural sector in the world. Nevertheless, as is the case with other rich nations, the USA obtains only a limited part of its income from the agricultural sector, estimated at less than 3%. The agricultural sector employs around 3% of the active population. Various agrofood multinational companies have their headquarters here. Among the most well-known are Monsanto, Quaker, Cargill, Kellogg, John Deer, American Home Products, Dupont, Pfizer, Mars, Pepsico, and ConAgra. There is a very dynamic process of enterprise consolidation in the private sector, and several of these companies may become amalgamated within the next five years.

3.2.1 Description of the research system

The USA has the largest agricultural research system of all the developed countries. Total public agricultural research in 1996 had a value of US$ 3,148 million and private research was estimated at US$ 3,961 million. Because of its size and structure, it is difficult to discern a specific orientation in the system. The public research system aims to improve the contribution of the agricultural sector to internal economic development, and to increase the competitiveness of US agriculture in international markets.

Public research is managed by two main components (figure 3.4). The first is the US Department of Agriculture (USDA) subsystem, which consists of three services: the largest is the Agricultural Research Service (ARS), which maintains 290 units and laboratories around the country. The mission of the ARS is (1) direct research toward developing and transferring solutions for national priority agricultural problems and ensure access to information to maintain high-quality food supply; (2) understand the nutritional needs of the population; (3) maintain a competitive agricultural sector; (4) highlight natural resources and the environment; (5) provide economic opportunities for rural citizens and communities and for society in general (USDA/ARS, 1999).



Source: K. Day-Rubenstein, personal communication; and Alston, Christian, and Pardey 1999.

Figure 3.4: Financing flows and sources, and agricultural research activities in the USA, 1996 (millions of US$)

The second-largest component of the USDA is the Economic Research Service (ERS), centered around Washington, DC. The ERS performs economic analyses of topics related to agriculture, nutrition, environment, and rural development with emphasis on issues such as efficiency, effectiveness, and equity, with the aim of contributing to public and private decision making (USDA/ERS 1999).

The US Department of Agriculture Forestry Service (USDAFS) is the third component of the USDA subsystem. The entire subsystem has a total budget of US$ 936 million, all of which comes from federal sources (30% of total public investment). USDA works mainly on topics of national interest. More than 50% of its research is classified as basic; while another part of its research agenda is to support regulation and federal legislation.

The second component of US public research is the State Agricultural Experiment Stations (SAES), which are linked to the Land Grant Universities. SAES receive US$ 2,212 million in financing (70% of the total) from three sources: US$ 715 million from federal funding through the USDA as well as other agencies (32% of SAES financing); US$ 1,050 million (47%) from state funds, and US$ 447 million (21%) from honoraria, sales, and contracts with the private sector. All states have institutions that belong to the SAES subsystem. The exact mission of the different components of the SAESs vary according to state needs. The SAES also work on topics of interest to the state and, frequently, according to state demands. Nevertheless, many SAES research projects have impacts outside of the state where the research is performed and, in recognition of these additional impacts, the federal government supports state research.

From the point of view of financing and execution, private research is quite separate from public research. There is a certain amount of implementation of private research within the public system through the SAESs, but the vast majority of private research (around US$ 4 billion) is financed and executed separately. In 1992, private research was focused mainly on agrochemicals and post-harvest processing (each receiving around 33% of the total). About 12% was spent on machinery and genetic improvement, and 9% on veterinary and pharmaceutical research.

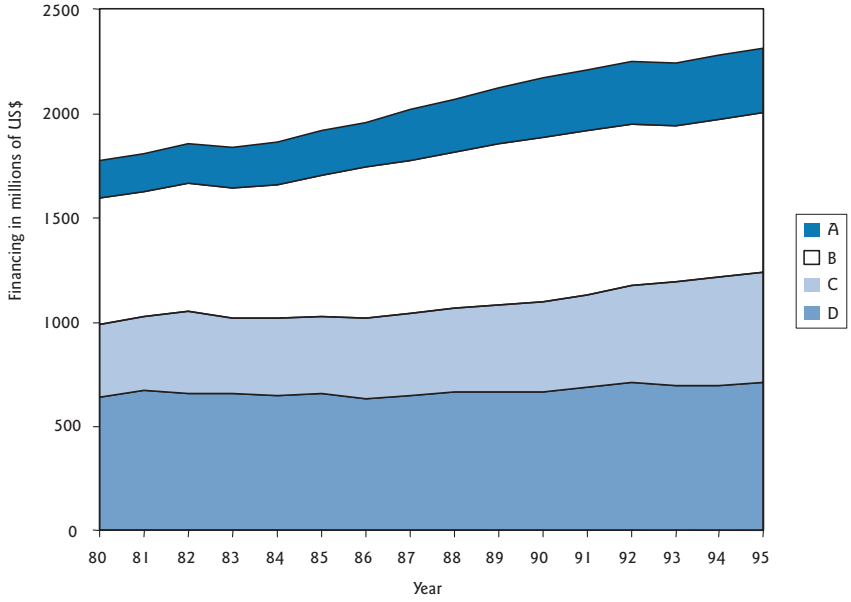
Structurally, the US research system has been very stable over the past 100 years, and modifications over the past decade have been incorporated without major structural changes. One peculiarity of the US system is that the distribution of responsibilities does not follow the expected pattern. In general, it is considered that basic research is the responsibility of universities and that applied research is best implemented in research institutes (compare this with the Netherlands and Switzerland, where applied research is increasingly being funded privately). Nevertheless, in the USA, universities are linked to state demands that, in general, have a more applied character, and the USDA research institutions are linked to national demands that, in general, have a more basic character. The evident success of the system tends to suggest that there is no unique recipe for defining research responsibilities.

3.2.2 Trends in public and private financing

Figure 3.5 shows that, since the beginning of the 1980s, the growth of the state subsystem has been more rapid than that of the federal subsystem. The principal causes of this change in relative importance are the federal government's efforts (beginning with the presidency of Ronald Reagan) to reduce fiscal deficits due to a drastic fall in federal revenues (22% between 1988 and 1999). Because of these efforts, there was a reduction in real terms in USDA resources for agricultural research. This reduction was not equal in all expenditure categories. The restricted contributions to the SAES subsystem (contracts and competitive funds) actually increased in importance. Since the USDA subsystem depends on federal agricultural funds as its only source of financing, there was a reduction in its level of activity (Huffman 1999).

The situation at state level was quite different. State governments experienced a real-term growth in income of 27% and therefore did not need to cut budgets with the same severity as the federal government. Nevertheless, state governments did not increase their contribution to the SAES subsystem in real terms. If the SAES subsystem had depended solely on unrestricted federal and state funds, its financial base would have shrunk by 4.8% between 1988 and 1999 (Huffman 1999).

The SAES subsystem was able to improve its financing by 2.2% by obtaining funds from less traditional sources. First, it gained access to restricted USDA funds through contracts or competitive funds; second, it considerably increased its access to federal funds from non-USDA sources such as the National Science Foundation (NSF), the National Institute of Health (NIH), the Energy Research and Development Administration (ERDA), and the Department of Defense (DoD); and third, the value of its industry contracts increased.



A: Other financing for the SAES subsystem
B: State financing for the SAES subsystem
C: Federal financing for the SAES subsystem
D: Financing of the USDA subsystem

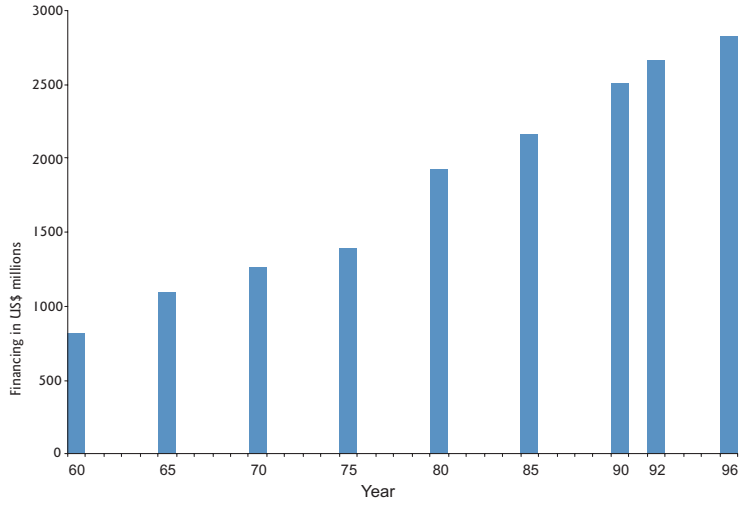
Source: Alston, Christian, and Pardey 1999

Figure 3.5: Financing of federal (USDA) and state (SAES) agricultural research, 1980–95 (millions of constant 1985 US$)

In summary, the reduction in the availability of federal funds has had the following effects:

- The USDA is committed to improve the use of its funds, giving priority to the federal subsystem (in other words, reducing cuts) and putting more emphasis on restricted funds (and less on nonrestricted funds) in its support to the SAES subsystem.
- A similar reaction occurred at state level to reduce, in real terms, the availability of funds for the SAES subsystem.
- The search for financial diversification within the SAES subsystem has had success, with greater access to restricted USDA funds, nonagricultural federal funds, and private funds. In this process, the SAES components are increasingly profiled as research implementers willing to employ their capacity according to expressed demands. This is a similar process to that occurring in the UK and the Netherlands.

Although the data is incomplete, it is evident that over the past 15 years, growth in agricultural research has been mainly in the private sector. As shown in figure 3.6, by the mid-1980s, private research had a value of US$ 2,167 million, which increased in 1996 to US$ 3,961 million. In real terms (corrected for inflation), private research grew by more than 4% per year, increasing the participation of the private sector to 52% by the mid-1980s and to 56% in 1996. The availability of research techniques (biotechnology) that result in products that can be patented, and the support of the legislative framework for intellectual property rights, have promoted the development of private research (Fuglie et al. 1996; Huffman 1999).



Source: Economic Research Service, calculated from Klotz et al. 1995 and K. Day Rubenstein, personal communication.

Figure 3.6: Private agricultural research expenditures in the USA, 1960–96 (millions of constant 1985 US$)

3.2.3 Changes in the research context

Technological demands. Fuglie et al. (1996) describe the changing demands on the agricultural research system in the USA, and discuss these demands using the concept of the "affluent society." Although American consumers reduced food expenditure from 16 to 12% of their disposable income between 1988 and 1998 (Huffman 1999), a large part of this expenditure relates to food processing, marketing, and distribution. Therefore, the need to reduce food production costs is becoming less important. Consumers' concern with health, nutrition, food safety and quality, convenience, environment, and ethical aspects such as animal welfare, are becoming more important than the cost of producing food. In fact, between 1992 and 1997, nutrition was the theme that increased the most, from 5.8% to 7% of total research expenditures. It is interesting to observe that attention to environmental considerations has diminished in the USDA subsystem (federal), while it increased in the SAES subsystem, reflecting the fact that many environmental problems are local in nature.

Fuglie et al. (1996) and Huffman and Just (1998) also argue that emphasis in the public system should increasingly be placed on the production of public goods, which implies greater attention to basic research, to research with results that cannot be appropriated (for example, improvement of non-hybrid varieties), and to research that adds knowledge about public and private decisionmaking.

Three additional aspects merit attention in the discussion of technological demands in the USA:

1. The new demands have not replaced traditional demands for productivity and competitiveness, but have become integrated with them. The USA wants to maintain its strong position in the world agricultural market and does not see a conflict between the development of the agricultural sector and total national welfare, as is the case in European countries.
2. In Australia and Europe, the public nature of applied agricultural research is the subject of high-profile discussion, but it has a lower priority in the USA. The explanation is that the USA has a very large internal market, and much of the effect of research is transferred to the consumer in the form of lower prices. In other countries, the effects of agricultural research are transferred principally to producers, thus giving them the opportunity to be more competitive in the world market.

3. Huffman (1999) argues that the growth in Total Factor Productivity (TFP) of 2.9% between 1988 and 1998 was high and acted as a brake on the demand for research and technology.

Changes in the organization of science and research. The new opportunities provided by biotechnology represent a very important change in the USA. According to Clarke (1998), plant or animal geneticists that work at a molecular level have increased their presence, whereas traditional breeders are only found and contracted with difficulty. The USA has been a leader in the development of biotechnology and in capturing the results (for example, transgenic soy varieties resistant to Glifosato or to Roundup). The development of new biotechnologies has been accompanied by the development of legislation that permits research results to be protected and marketed. In addition, the development of biotechnology and its use in consumer products has encountered little resistance from the public.

The development of biotechnology is encouraging greater interaction between agricultural and nonagricultural sciences and emphasizing the increasing importance of nonagricultural sources of federal funds. In the private sector, multinationals such as Monsanto, Dupont, and Dow are developing their capacity in life sciences and in pharmacology, agriculture, nutrition, medicine, etc. The overall scientific concept is guiding their actions, while previously they were guided by sectoral visions.

Huffman (1999) mentions advances in information sciences as a major development, but it seems that this has had less strong and less direct effects on changes in agricultural research than has the development of biotechnology.

Public and private responsibilities. Agricultural research trends in the USA have been influenced by changes in thinking about public and private responsibilities, but to a lesser degree than in the UK and the Netherlands. The departure point for much of the change has been more pragmatic: the need to balance the federal budget. In response to considerations regarding public or private goods, the research system has begun to emphasize problems related to environment, food safety, nutrition, information needed for decision making, and basic research. Other elements strongly linked to the theory of public goods, such as the separation between decision making and implementation, have had little influence.

A concept that is becoming more prominent in relation to public and private responsibilities is that of the "enterprising government" (Osborne and Gaebler 1993). This concept puts less emphasis on the distinction between public and private functions and focuses more on the definition of clear objectives and evaluation parameters (or accountability) and the development of strategic alliances and proactive behavior in seeking financing and defining responsibilities. The basic idea is that entrepreneurial behavior is valid in any organization, and the essential question is how to promote it. The behavior of the SAES subsystem largely reflects Osborne and Gaebler's ideas.

A third dimension that has played a role in defining the role of public research is the balance between federal and state responsibilities. While in European countries, the debate about government tends to imply a reduction in total government spending, in the USA, the debate about the government has implied a shift in emphasis from federal to state government programs and spending.

3.2.4 Responses and institutional innovations

Governance. Over the past 20 years, the American system has experienced little change in its basic structure or in the legal constitution of its essential components. Changes in governance have occurred, and these have taken place through planning, follow-up, and evaluation procedures. The Government Performance and Results Act (GIPRA) requires strategic planning and the production of annual reports for all federal agencies. The GIPRA was created to increase transparency regarding

government performance and to make agencies more accountable to federal auditors. In 1998, the GIPRA was replaced by the Agricultural Research, Extension, and Education Reform Act (AREERA). This requires the development of work plans, mechanisms for stakeholder participation, and external review procedures. According to Huffman (1999), the intentions of these acts are commendable, but their implementation is creating too much bureaucracy.

Nevertheless, the accounting practices of the SAES are apparently not very strict. Part of federal and state funds are used to maintain fixed personnel and teams (the scientific base), and it is the money that is obtained through public or private contracts or through competitive funds that defines the research agenda. The problem of "the tail wagging the dog" shows the incipient concern with respect to private financing (Fuglie et al. 1996). Two factors can explain why the concern is not greater: first, a good auditing system, together with strict research follow-up, limits the possibility of loss and abuse of funds; second, close monitoring on the part of stakeholders and their representatives obliges the SAES to maintain a relevant research agenda. Close monitoring also explains the apparent satisfaction of users with the system's guidance, even though they do not have great financial influence.

Although there has been no decentralization process per se, the change in the relative importance of federal and state research, combined with the emphasis on environmental topics that require a regional focus, has created a certain degree of movement in terms of influence toward the SAES subsystem.

The AREERA requires stakeholder participation (including nontraditional stakeholders) in research governance, but it doesn't indicate how this should be realized. The sponsorship of the system rests firmly with the USDA.

No privatization occurred within the system, nor were there any efforts made to increase the autonomy of its different components. Instead, the AREERA reduced the effective autonomy of the involved organizations. What did happen was that a larger space was created for the private sector that finances agricultural research in the public system. The viability of this participation has increased due to a strengthening of the legal framework. Section 3.2.5 discusses two aspects related to this policy.

Financing. A definite change in financing has been seen and is related to a move from nonrestricted financing by means of formulas to financing through contracts or competitive funds. As competitive funds have grown in importance, their coverage has become broader. While prior to 1995 they covered high priority basic research, after this they also covered more applied topics and multidisciplinary research.

The growth in financing of the SAES subsystem has stemmed from nontraditional sources such as nonagricultural federal agencies and the private sector. Since 1985, it has been possible for producer associations to finance and direct agricultural research through a system of voluntary surcharges (check-off system). The system continues to function, but producers have doubts about the results of their investments, which suggests that the benefits of this type of applied research are not channeled as well as they could be.

Research implementation. The importance of joint ventures between the public and the private sectors has increased a great deal in the USA. Within these joint ventures, the private sector has the first right to exclusive use of the research results. In this manner, the public sector makes a great compromise with respect to one of its principal functions, which is to improve access to knowledge. Joint ventures are useful for mobilizing the scientific capacity of the public sector, but there are two types of associated risks:

1. When the accounting system is not very clear (especially when calculating fixed costs), joint ventures are likely to result in a large subsidy to private industry. If this is the case, research

governance could be affected by certain private industry interests. If these subsidies are not explicitly politically supported, the support for public research could be reduced.
2. The dissemination of knowledge is reduced with the exclusive rights provision. In the long term, public and shared knowledge will be replaced by segmented and protected knowledge, making the process of innovation less efficient.

As an example, the public sector has completely withdrawn from developing hybrid seed and other seeds whose performance is conditioned by technology packages (e.g., soya and cotton). In other fields, the private sector has improved its capacity to capture profits through more favorable intellectual property legislation. On the other hand, the private sector has abandoned the development of open-pollinated or autogamous seed where there is no possibility to earn profits, whereas the public sector maintains this type of technology development.

The public sector is placing increasing emphasis on basic and precompetitive research, while the location of the SAES in the Land Grant Universities considerably facilitates the movement toward basic research. Locating a large portion of agricultural research within universities has another advantage. Basic research often contributes to the accumulation of knowledge. Through the universities' educational programs, the SAES can diffuse results not only in the form of technologies or publications, but also in the form of graduates equipped with scientific knowledge. In a world where knowledge is increasingly a determining factor in competitiveness and development capacity, the SAES plays a very important role by feeding the active knowledge base.

Competitive funds provide an incentive for multi-institutional projects. While there is less emphasis on international collaboration compared to research in Europe, some international programs are maintained (e.g., the collaborative research and support projects), but they carry little weight or importance.

3.2.5 Noteworthy initiatives

Some of the special developments in the USA include the following:

1. Cooperative Research and Development Agreements (CRADAs) were first established in 1987 and were designed to facilitate the transfer of technology from federal agencies (of the USDA subsystem). CRADAs join federal researchers with universities, private companies, and nonfederal public entities. The scientific capacity of the federal laboratories are combined with the applied or commercial experience of the partners, and the partners contribute to financing and have rights to be the first to evaluate the results as well as having exclusive access to the data obtained.

   A CRADA can thus be a means for developing, marketing, and privatizing technologies. As can be observed in table 3.3, by the mid-1990s, some 227 CRADAs in the private sector mobilized an annual total of US$ 61 million. Although the growth in CRADAs has been satisfactory, the figure is modest. This suggests that the interdependence between federal research and technological development in the private sector is not very great, or that it is not being adequately channeled through the CRADAs.
2. Another significant development is the change in federal financing mechanisms for the SAES. Financing through formula funding has been replaced by project financing. Formula funds were assigned to each SAES according to the size of the state, the importance of the agricultural sector, the state contribution to the SAES, and other factors. The federal contribution to each SAES was calculated by means of a formula and transferred as an unconditional payment. In 1970, 61% of federal financing for the SAES was in the form of formula payments and 39% percent was in the form of project funding. The 39% was composed as follows: 2% in special noncompetitive funds, 8% in USDA contracts, and 29% in projects with federal nonagricultural entities.

Table 3.3: Development of CRADAs in the USA

Year	Number of CRADAs	Value involved (US$ millions)
1987	9	1.6
1988	48	8.7
1989	86	15.6
1990	104	18.9
1991	139	25.6
1992	160	30.0
1993	185	34.0
1994	212	61.3
1995	227	n.a.

Source: Fuglie et al. (1996)

In 1994, only 30% of SAES funding came from formula funds, 9% from competitive funds, 12% from special noncompetitive funds, 12% from USDA contracts, and 37% from projects with nonagricultural federal entities. In 1998, 17% of the federal contributions were competitive. The changes imply that the federal government is achieving greater control over the orientation of research in the SAES, leading to the problem that "the federal tail wags the state dog." If state funds become increasingly subject to federal conditions, there is a danger that the flexibility of the system will be reduced.

The move toward competitive projects has been the subject of some criticism. Huffman and Just (1998) argue that, to increase the probability of financing through competitive projects, fewer risks tend to be taken and therefore there is less innovation. At the same time, the risk of rejection presents a negative incentive for researchers, who need additional compensation to participate in competitive funds. On the other hand, competitive funds have proved to be a good mechanism for influencing system orientation toward a certain discipline or problem, or toward collaborative projects. Their utility as a guidance instrument appears to be greater than their utility as an instrument to increase average productivity within the research system.

The final change in financing that merits attention is the growth in nonagricultural federal funding. The federal departments of health, energy, development, and defense perceive that the SAES systems contain experience that is relevant to their needs. This implies that the division between sectors has diminished.

3. The strengthening of intellectual property rights merits special attention. Originally, a large proportion of agricultural inventions were considered to be "products of nature" and were not subject to patenting. More recently, the protection of agricultural inventions (e.g., varieties and breeds) and of research and transformation methodologies (e.g., identification of genes and gene splicing) has been permitted. In 1970, the Plant Variety Protection Act gave the breeder the sole right to multiply a variety commercially. This protection was weak since it did not cover similar varieties, and it permitted farmers to multiply seed for their own use as well as to sell part of the multiplied seed. In 1994, these exceptions were eliminated and the length of protection was increased from 17 to 20 years.

   In 1980, in the case of a micro-organism created through genetic engineering, the Supreme Court decided that living material was subject to patenting. This interpretation was later extended to plants and animals. Between 1970 and 1992, growth in private research on genetic improvement was rapid. Nominal investment increased 15 times from US$ 26 million to 400 million. In comparison, in mechanical research, nominal investment increased by only 4.5 times. In biotechnology, figures are available only since 1985; these show a substantial increase in absolute value.

The impact of property rights on the growth of private research is evident. Nevertheless, the evaluation of this legal change needs to take into account three additional aspects: (1) growth in private research is based on strong public research. There has been some substitution of activities during the period when stronger property rights were established but, in general, the focuses were complementary; (2) Huffman's study (1999) suggests that the private research entity receives only up to 50% of the technological earnings. The rest is transferred to agricultural producers and consumers. Therefore, the effects of distribution have been more modest than was initially anticipated; (3) with patent systems in place, the private sector has greater incentives to invest in research and the effect on total growth of the sector is less evident. In the previous system, the public availability of results improved access to new inventions and facilitated the accumulation of knowledge. The secret character of much private research implies less transfer of technology and could result in a lower average return to research.

4. The joint venture between Novartis and the University of California at Berkeley is an initiative with great potential impact. Novartis is supplying US$ 25 million between 1999 and 2004 to finance research projects with the Department of Plant and Microbial Biology, and it will give scientists in the department access to its germplasm collection. The funds will be channeled through a committee, controlled by professors of the University, but with Novartis participation. The committee will evaluate research proposals and allocate funds. With the funds that it offers and federal funds, Novartis has priority in obtaining patents for the research results and this priority will be in proportion to its financial contribution to the department. Novartis can negotiate licenses for patents that will remain with the university for a period of up to 60 days before research results are published. The professors and researchers who are working with Novartis funds cannot work for other companies.

   The exclusivity clauses in the contract between Novartis and the university have caused a certain amount of media attention, since they can be interpreted as efforts to monopolize scientific capacity. The open nature of the contract has also led to questions about the future independence of the university in terms of the definition of its research agenda.

3.2.6 Conclusions

Although the agricultural research system in the USA is very large, it is relatively simple in structure. It depends on two large subsystems: federal and state. The federal subsystem receives federal financing and concentrates on problems at a national level. The state subsystem receives state and federal financing in recognition of the spillover effects between the state implementing the research and the rest of the country (Olson 1969). The state subsystem also receives funds from private and other government sources. Because of the diversification of its funding, the state subsystem has grown faster than the federal subsystem.

This simple structure has some very attractive features. One of these is the central role of universities, which permits knowledge to be diffused through publications, technologies, and graduates; it also permits the employment of numerous scientific personnel and maximizes the creative potential of students. At present, public agricultural research systems in many countries concentrate on basic research and are attempting to increase the roles of universities; in the USA, this can be achieved within the existing system.

The changes in the US system have not affected its structure, but have affected the procedures operating within it (planning, follow-up, evaluation, and financing) as well as the system's culture. The federal government is attempting to increase its control over the effectiveness and efficiency of the system by introducing various procedures. The change in culture can be summarized by the concept of "enterprising government." The SAES subsystem has been particularly effective in diversifying its financing sources. Both the USDA and the SAES subsystems are increasingly involved in joint ventures with private industry. In a partial accounting system (centered on operation costs), these joint

ventures can imply considerable implicit subsidies to private partners and will almost surely create political opposition in the future. Another risk of joint ventures is that the generation and dissemination of knowledge is restricted to the contract partners and that the generation of spontaneous innovations will be limited due to the absence of new public knowledge.

Joint ventures are concentrated on large-scale industry such as Novartis, Monsanto, and Dow, where the interest of the large-scale commercial sector in collaborating with the public sector has been reinforced by advances in intellectual property rights legislation. The role of primary producers in research guidance and technology generation is less clear. Legal norms meant to increase the role of stakeholders in research do exist, but they do not indicate which stakeholders should be involved or how to interest them.

While joint ventures are increasing, it must be remembered that the size of joint activities is very small in comparison with the volume and growth of private activities. For example, the CRADAs (federal joint ventures) move a total volume of funds that is less than 1% of the total investment in agricultural research. Therefore, it may appear that alliances with the private sector constitute only one element of a strategy to maintain the relevance of the public agricultural research system. Public research will be more effective if it creates an environment that promotes innovation through the generation of basic and strategic knowledge, and if it concentrates on broad diffusion strategies (publications, technologies, education, collaboration networks, and alliances).

The effects of the noteworthy initiatives in the US system are summarized in table 3.4. The CRADAs reinforce the interaction between the public and the private sectors and constitute an innovative mechanism for transferring results. They stimulate stakeholder participation, but they may also contribute to a less clear focus within the public system. The changes in financing mechanisms have given greater influence to the financiers and have placed researchers in the role of implementers. The introduction of the check-off system increases stakeholder participation in the research system.

Table 3.4: Effects of Noteworthy Changes in the USA

Criteria	CRADAs	Financing mechanisms	Intellectual property legislation	Alliance Novartis-Berkeley
Separation of financing and implementation		+		
Pluralist structure			+	
Focus on public goods	–		–	–
Public-private complementarity	+		+	+
Institutional autonomy		–		–
Stakeholder participation	+	+		+
New models for transfer of technology	+			
Clear and positive legal structure			+	

Source: Developed by the authors.

Changes in intellectual property legislation have contributed to a clear and positive legal structure, to facilitating interaction between public and private sectors, and to facilitating the entrance of new stakeholders into agricultural research, since results can be protected. Nevertheless, it creates a desire within universities to obtain patents and financial benefits from research results, instead of making these results available to the public. The alliance between Berkeley and Novartis is one ex-

ample of a greater complementarity between the public and the private sectors, and it increases the participation of one of the stakeholders. Nevertheless, this alliance could run the risk of deviating from a research agenda oriented toward public issues and it could also affect the autonomy of parts of the University in terms of the ability to define their own directions.

In summary, the changes in the USA have been absorbed within the system's structure. Many of the changes have been meant to improve collaboration between the public and the private multinational sector. In the short term, these modifications may accelerate the innovation process. In the long term, an articulation between these two sectors, with clearer responsibilities for each, may be a condition that is needed if political support is to be maintained and a sustainable intellectual climate for innovation is to be created.

3.3 The Netherlands

The Netherlands has a relatively small surface area of around 37,000 km^2, with some 15 million inhabitants. The land is flat, and nearly all of it has good agricultural potential. Forty percent of the area is below sea level, and the groundwater level is maintained below the surface only through continuous pumping. Per capita income in the mid-1990s was around US$ 22,000 per year (World Bank, 1998). The Netherlands has good sea access and is a center of transport and commerce. It is a founder member of the European Community. Although small and densely populated, the country is the world's third largest exporter of agricultural products. It exports US$ 37.1 billion and imports US$ 22.3 billion per year in agricultural goods. In 1994, its commercial agricultural surplus was US$ 14.8 billion. It is the base of operations for some important agroindustrial multinationals such as Unilever (shared with the UK), Numico (specialized food and nutritional products), and Nutreco (animal feed, meats, and fish), as well as various large milk and potato cooperatives.

3.3.1 Description of the research system

According to the Ministry of Agriculture, Nature Management, and Fisheries (LNV), the mission of the public research system in the Netherlands is to create or improve the conditions for a competitive, sustainable, and secure agricultural sector. Its objectives have undergone considerable change, from a focus on production and productivity to more emphasis on sustainability of production, environmental quality, animal welfare, food safety, and sustainable land use. The new objectives reflect a change in the influence of different stakeholder groups. Prior to the 1980s, the system was influenced mainly by agricultural producers; after this, the system returned (at first sight) to giving priority to public interests.

The Netherlands supports high agricultural research expenditures and maintains a complicated research structure even after various reorganizations. Public research expenditures represent approximately 4% of Gross Agricultural Product. There are three principal implementation components under the umbrella of Wageningen University and Research Center (WUR):

1. Wageningen University and Research Center, which in 1995 had a budget close to US$ 197 million (34% of the total public agricultural research budget). Of this amount, 54% is oriented toward agricultural sciences and the remainder is for lateral disciplines, such as agroindustrial, environmental, social, and biological sciences. The University focuses on basic research and depends on the LNV for financial support.
2. The Agricultural Research Department (DLO), which has a budget of US$ 229 million (40% of the total), and focuses on strategic research. Previously, the DLO was a branch of the LNV, dedicated to research. In 1999, the DLO had 11 institutes and was in the process of consolidation.
3. The Organization of Applied Research Stations (OARS) has a budget of US$ 66 million (11%). There are nine centers within the OARS. This was also previously a research branch of the LNV.

The three components share their governing board and top management through the WUR. One of the purposes of the WUR is to concentrate scientific capacity in two locations (Wageningen and Lelystad) to obtain greater synergy and a critical mass, and to avoid duplication.

Other implementation components of the Dutch system are

- the Faculty of Veterinary Medicine at the University of Utrecht, which depends on the Ministry of Education and Science and has a budget of US$ 24 million per year (4% of the total);
- the Food Division of the Netherlands Applied Technology Organization (TNO). In 1999, its budget was US$ 64 million (11% of the total). TNO is a private, nonprofit organization that carries out research for the public and private sectors. TNO is dependent upon the Ministry of Economic Affairs.

Two components play an important role in coordinating the Dutch system:

- The National Council for Agricultural Research (NRLO), whose original function was to plan and coordinate agricultural research. System restructuring began in 1995. Now the NRLO is an advisory council for the LNV and is in charge of forecasting studies for the agricultural sector, particularly advice on research to meet policy needs. In its new function, the NRLO is focused more on defining research directions and shared sectoral goals, and less on timely coordination.
- The Department of Science and Knowledge Transfer was created in 1995 as part of the LNV. It is in charge of defining research policies, education, and agricultural technology transfer.

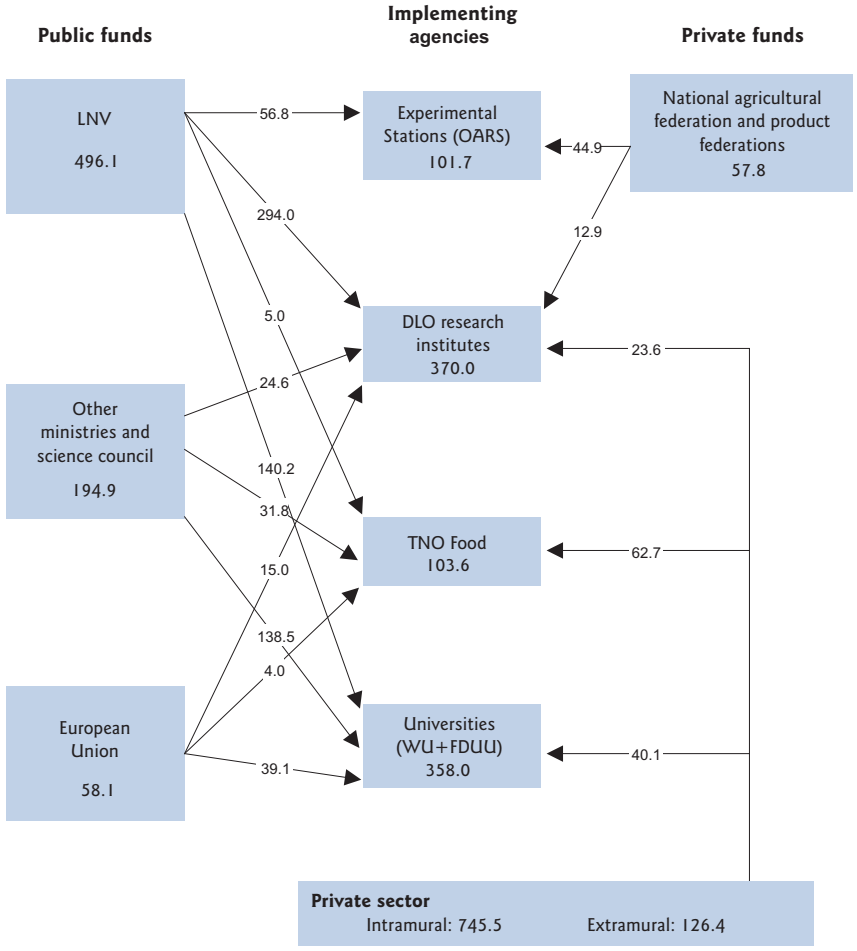
Figure 3.7 shows the relationship between the implementing entities and financing sources within the Dutch system. Public research financing comes from different sources: 52% is from the LNV, 15% is from other ministries, 6% comes from the European Commission, 5% from the National Science Foundation, 6% from the Producer Federations, and 16% from private industry. LNV participation in public research financing reduced from 80% in the 1970s to 67% in the 1980s and to around 50% in the 1990s. The participation of producers in applied research financing (OARS) is quite high, at 44%.

In the past, the extension service received a 50% subsidy, but gradually this has been replaced by government support for priority programs, and the extension service has been privatized.

The Netherlands supports both public and private agricultural research. In 1995, private agricultural research expenditures were estimated at DFl 745 million (US$ 373 million). Nearly 20% was destined for research related to agricultural production (predominately in the seed industry), 57% was for food research, and 23% was directed toward research on agrochemical and veterinary inputs (Alston, Pardey, and Smith 1998).

3.3.2 Trends in public and private financing

As can be seen in figure 3.8, agricultural research financing has been relatively stable over the past 20 years, with a slight increase of 1% per year. From the beginning of the 1980s until the mid-1990s, growth in research was concentrated within the universities, especially in Wageningen (basic research), and in TNO (food research). The DLO and the OARS have had very low levels of financial growth. This is due largely to the fact that the government is increasingly debating whether applied agricultural research is relevant per se. As in the UK, the Dutch government has decided that applied research should be more client-contractor oriented. If the client does not provide the financing, the research cannot be justified. Clients have communicated more directly with the DLO since privatization (which took place after 1995). As a consequence, some DLO institutes (e.g., the institute dealing with processing) are experiencing very large budgetary growth while significant growth has occurred in the DLO as a whole.



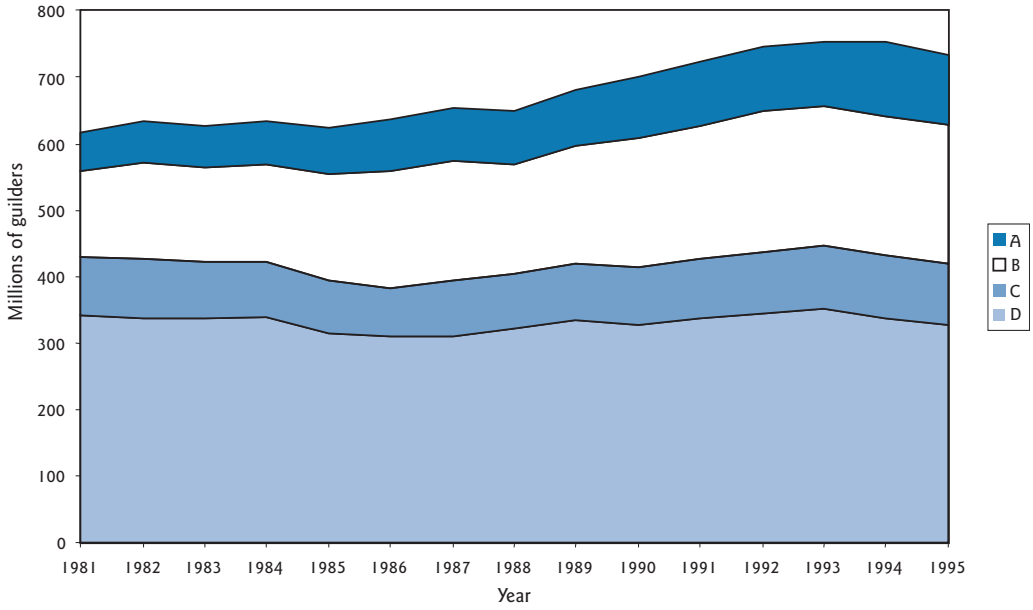
Source: Roseboom and Rutten (1998)

Figure 3.7: Financial flows in the Dutch agricultural research system, 1995 (millions of Dfl)

The growth in Wageningen University financing is due mostly to an increase in Council of Science funds, which, in the mid-1990s, represented nearly 55% of the University's funding. The growth in contract research reflects Wageningen University's flexibility in obtaining funds.

The financing of the OARS system has also been very stable, partly due to the form of financing. Almost half of all financing came from production surcharges imposed by the National Federation of Agriculture and the Product Federations. The government complemented this financing through a matching grant. Therefore, as long as the value of agricultural production was more or less constant, the OARS budget did not fluctuate substantially. In 1997, the National Agricultural Federation was discontinued due to a labor conflict. The role of fund collection was taken over by the Product Federations, so total OARS financing has not changed.

The increase in food research (TNO) is due to two phenomena: (1) increasing concern for consumer protection; and (2) TNO has an increasingly independent position, resulting in greater access for the private sector, which finances around 60% of its research.



A: TNO expenditures
B: University expenditures
C: OARS expenditures
D: DLO expenditures

Source: Roseboom and Rutten 1999.

Figure 3.8: Expenditures of principal institutions within the Dutch agricultural research system, 1981–95

The conclusion appears to be that basic research responds more to public interests than strategic and applied research; the demand for research services has been increasingly oriented toward topics that affect consumers; and, in response, the system was reorganized to allow greater access to nontraditional clients and sponsors.

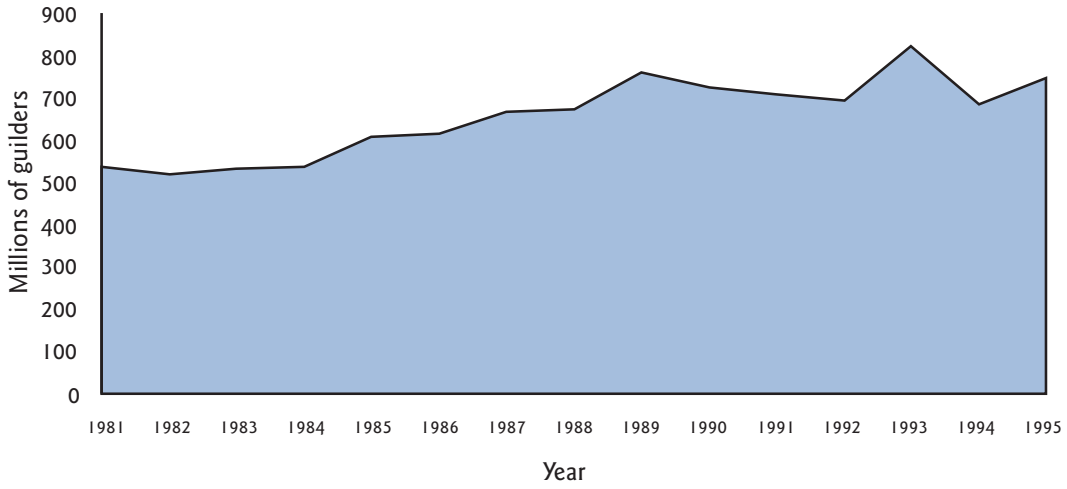
Since the beginning of the 1980s, private research (figure 3.9) has grown twice as fast as public research. This growth is related to the growth in certain input (seed) and food (milk, potatoes and their byproducts, highly processed products) industries. The importance of market research and new product development in the private sector has been notable. It is not always possible to separate product development from adaptive research (Roseboom and Rutten 1999).

3.3.3 Changes in the research context

Technological demands. Until the 1980s, Dutch research concentrated on the interests of the agricultural producers. Public concern for agricultural surpluses, for contamination and destruction of ecosystems, and for animal welfare, has led to a change and since 1982, the mandate of the Ministry of Agriculture has widened to include recreation and environmental management (Meer 1999).

Three other changes in technological demands should be recognized (Rutten 1999):

1. Specialization in agricultural production has resulted in the dispersion of professional interests and aptitudes. For example, nearly all horticultural producers attempt to develop their unique comparative advantage by specializing in one type of flower or vegetable. The level of dispersion and sophistication in the Dutch agricultural sector is no longer useful for generating generic technologies, and branch technologies (for example, rose production) are also no



Source: Roseboom and Rutten 1999

Figure 3.9: Private sector research expenditures in the Netherlands, 1981-1995

longer useful. In their place, producers seek knowledge that can be applied in their own specific environments.

2. Linked to the previous point is the fact that new agricultural specializations require specific knowledge, such as ecological production, integration of production, and nature conservation, and regional products.
3. Instead of optimizing agricultural production, more emphasis is now being placed on product changes, and technological problems are being identified from the demand side.

The changes in technology demand in the Netherlands reflect a type of agriculture that has moved to a new phase through industrialization. Until the 1980s, technology production resulted in a relatively uniform and productive sector, but, at the same time, it led to contamination and had little interaction with consumers. The new technology demands reflect a post-industrial agricultural sector with more differentiation and a greater demand for environmental and consumer information. There is more emphasis on creating an agricultural sector that can operate within a multifunctional rural space that includes provision for recreation, nature management, transport, construction, etc.

Changes in the organization of science and research. New fields such as biotechnology and information science have caused a blurring of traditional lines that separated agriculture from other types of scientific research. In addition, the traditional divisions between applied, strategic, and basic sciences have become less clear. Therefore, the distribution of responsibilities between the different components of the agricultural system and nonagricultural research suppliers has also become more ambiguous. Much research has become independent of the place of execution, which permits greater concentration of research in certain locations (e.g., Wageningen and Lelystad).

The classic agricultural disciplines (e.g., plant breeding) appear to be diminishing in importance in relation to the molecular, food, and environmental sciences. In the social sciences, economics and sociology are giving way to business administration, geography, and political sciences.

A third important development is that knowledge is increasingly becoming a commercial product. Those on the demand side know best how to define results expected from a research project, and they are able to negotiate these results with different research suppliers. The consequence is that certain agricultural research projects that previously would have been carried out by Wageningen

University or the DLO are contracted to other institutes. At the same time, the old agricultural research suppliers also obtain contracts in areas on the margins of traditional agricultural research.

Public and private responsibilities. At the beginning of the 1980s, the Ministry of Agriculture and its dependents were felt to be over-bureaucratic and sycophantic. With respect to Wageningen University and the DLO, the feeling was that financing from the Ministry of Agriculture did not have a significant effect on the direction of research efforts. Part of the change in attitude toward the agricultural sector is due to the gradual erosion of the sectors' political influence. As in the UK, the agricultural sector was perceived to be reaping the benefits of European Community subsidies rather than looking after the countryside. Since 1982, the public sector in the Netherlands has gone through a structural adjustment process involving the following elements: (1) reduction of the government's budget; (2) separation of policies and implementation; (3) concentration on public themes and the devolution of other responsibilities to the private sector; (4) emphasis on efficiency and accountability; and (5) autonomy or privatization of certain public services. Government responsibility for maintaining structures and institutional dialogues in the different sectors (for example, employees' or employers' organizations, producers' or consumers' organizations) was also reduced. These elements have had a great, although selective, influence on the changes observed in the agricultural research system.

3.3.4 Responses and institutional innovations

Governance. The Dutch system has experienced very major changes in governance. One of the first to occur was the creation of a department within the LNV with responsibility for science and technology transfer policies (1989–94). The purpose was to centralize policy-making capacity within the Ministry rather than within the research system (where it was previously located). The department is responsible for research policies, budget allocation, and management and financial control of research, extension, and education. Another change was influenced by the centralization of this policy role within the Ministry: the NRLO, which formerly played a coordinating role through administrating many committees, changed their approach. NRLO now works through participatory think tanks and aims to predict future developments in the agricultural sector and their implications for research. This topic is dealt with in more detail in section 3.3.5.

Another important change has been the privatization of the DLO and OARS systems to create a more efficient institution that is more sensitive to market demands. This is discussed further in section 3.3.5. With respect to the sponsorship of the LNV, it can be seen that the Ministry has attempted to strengthen its position through merging the DLO and Wageningen University. The merger could be perceived as a defensive move as the LNV attempts to maintain its control and position with respect to the two most important institutions under its mandate. The LNV, which has attempted to strengthen its control over the research system, is also approaching the Netherlands Organization for Science and Research with the purpose of developing shared programs.

There are marked trends in other aspects of governance. The Dutch system is not decentralizing, but is trying to consolidate its strengths and gain greater benefits from its critical mass. The merger between the University and the DLO represents the centralization of decision-making power and implies a gradual concentration of governance in a few localities. The integration of stakeholders in the guidance and control system is also decreasing rather than increasing. Stakeholders' influence is increasingly exercised through financing certain types of work and not through having a voice in governance.

With the exception of the universities, no routine research evaluation procedures have been established.

Financing. Changes in agricultural research financing in the Netherlands follow the structural changes described in section 3.3.1. One of the main changes occurred when the LNV decided to finance research projects according to its own priorities, and not to provide funds to satisfy the priorities of others. Therefore, the matching grants system—in which producer organizations finance half and the government complements this amount—is disappearing. In certain cases, the LNV is willing to provide finance if private industry also participates in financing, but this cofinancing arrangement does not have the unconditional character of matching grants.

In LNV-financed projects, LNV pays full costs, including administrative and investment costs, etc. The DLO and the University have been obliged to develop a complete accounting system that permits them to take on this type of contract. The problem of indirect subsidies is avoided by paying full costs.

The use of competitive funds is restricted to certain areas. It is found in European Community financing and in some national schemes, where it is used to promote interaction between the private and the public sectors in generating innovation (Meer 1999). National cofinancing of European Community-derived competitive funds (where the latter do not cover full costs) occurs only if the topic corresponds to the priorities of the LNV. European-Community funds are attractive because researchers can obtain larger contributions (between US$ 100,000 and US$ 1 million) than offered by the Ministry for topics that are not included in its list of priorities.

Privatization and complete accounting permit funds to be obtained from private industry without fear of subsidies or hidden taxes. Certain DLO institutes (for example, dealing with post-harvest topics) have been very effective in obtaining these funds.

Research implementation. The merger between Wageningen University and the DLO was intended to secure greater research capacity and access to a broader experience base. The merger reflects the idea that, within a globalizing world where the agricultural sector has limited importance, scientific capacity will be concentrated in a few institutions where scientists will work on shared problems of international relevance.

Within the DLO and OARS, a system has been implemented where research is managed completely through projects with beginning and end dates and where strict control over budgets and progress is kept. In this system, project acquisition is becoming an important activity, although researchers were not expected to play this role in the past.

Within the Dutch university system, "research schools" that concentrate on specific themes have been established. These aim to create excellence and to coordinate research between diverse departments and universities. The research schools in which Wageningen University participates are able to broaden their base through contacts with the DLO. The foundation of the research schools was initiated through interaction between the Ministry of Education and Sciences and the Ministry of Economic Affairs.

Another joint initiative has been the establishment of "top technology institutes" with mixed financing. These institutes aim to create interaction between the generation of basic knowledge and its practical application. The Wageningen Food Centre (WFC), discussed further in section 3.5.3, is one example.

The third joint initiative has been the creation of the Agri Chain Competence Foundation, an organization that finances research to improve the performance of agricultural chains. The Foundation's budget comes from the general research budget of the LNV, and its establishment implies a change in priority toward chain management. The Foundation finances multidisciplinary and multi-institutional research and contributes to the strong position held by the Dutch agricultural sector in the management of its agricultural chains.

International research continues to be an important element within the Dutch system. Wageningen University and the DLO are the most successful suppliers for the European Community's competitive funds and the system continues to maintain many links with international research and other countries.

3.3.5 Noteworthy initiatives

The privatization of the DLO system occurred at the beginning of 1999, when it changed from a public organization into a nonprofit foundation. Its new legal status makes management and operations much more flexible, and any client can contract the DLO to carry out agricultural research. One of the biggest clients is the LNV. However, the Ministry has focused on distinguishing public and private-sector responsibilities. This has resulted in a clearer definition of the public-goods character of government financing in agricultural research. As a result, the LNV withdrew funding from near-market research (assessing direct relationships between private investment and return) and now concentrates on market failures (examining external effects, large-scale research, long-term results, and protecting people, animals, and the environment). The private sector now funds a considerable part of applied research.

The DLO therefore receives fees that are based on complete costs, including investments in buildings and equipment, personnel training, and management. In addition, the DLO has begun to look for research projects in other countries: for example, in 1998, the Institute of Livestock and Animal Health Research sold its products and services (research, vaccinations, diagnostic kits, etc.) to 47 countries (ID-DLO 1999). The changes mean that the DLO is taking on the characteristics of a consulting company, which has advantages for satisfying technology and development demands, but has disadvantages with respect to the development and maintenance of scientific capacity. The changes in the accounting system also create problems when the DLO interacts with the European Commission, since the latter does not finance complete costs.

Converting the DLO into a foundation is a bold move. In a globalizing world and an integrating Europe, research quality and relevance may be better expressed without public restrictions, giving the DLO the opportunity to raise projects in other countries where research quality considerations will overcome the desire to maintain national scientific capacity. If this does not occur, then the DLO system may find there is little demand for its services and little funding to maintain its scientific infrastructure.

The consolidation of Wageningen University, the DLO, and the OARS under a shared umbrella (WUR) is another major development. These organizations now have a single management structure to promote better use of their scientific capacity. The organizations maintain their identity but it is expected that, through joint management, benefits can be obtained from the comparative advantages of each: research capacity and infrastructure in the DLO and OARS, and scientific knowledge in the University. Consolidation permits the University to broaden its academic staff and it permits the DLO to broaden its experience and scientific prestige.

The consolidation is facilitated by the use of similar accounting systems based on complete costs. This is necessary because the merger brings together organizations with different legal statuses: the University is established under public academic law and the DLO and OARS under foundation law. Having similar accounting systems and direct compensation for the use of each other's services ensures that the University's public responsibility is respected. The consolidation happened only recently and it appears that some of the legal aspects involved remain to be resolved.

Without a doubt, the WUR consolidation expresses the importance given to the production, management, and exploitation of knowledge. In the new model (which is very similar in certain respects to the US Land Grant model), it is expected that knowledge will flow more easily from research to ed-

ucation and application, and that knowledge is the key to maintaining the Netherlands' position in global agriculture.

Another significant change is the transformation of NRLO from a coordinating entity into an entity in charge of long-term technological forecasting. In a model where technology demand is translated into a research service market for DLO and OARS, there is no great need for coordination. Nevertheless, it was feared that, in the new system, urgent demands would take attention away from long-term socioeconomic and technological development. For this reason, the NRLO has taken on the responsibility for forecasting—recognizing long-term developments and bringing them to the attention of the Ministry and the scientific system. It has been functioning in this manner since 1995 and, so far, evaluation of its efforts has been very positive.

The WFC was founded by the WUR, the TNO, certain private food industries, and industry associations (for example, the milk industry). It has lately undergone significant development. Concentrating on precompetitive research can generate knowledge that has broad applicability. By this means, the WUR generally avoids proprietary rights problems with respect to the use of results. The benefits are found further downstream, in the application of knowledge to achieve the participants' objectives. The WFC has been developed very recently and, for the moment, little information is available about its size and financing. Within a few years, it proposes to employ around 100 people, which corresponds to a budget of some US$ 10 to 15 million.

3.3.6 Conclusions

The Netherlands has a large and sophisticated agricultural research system serving an intensive and competitive agricultural sector. The role of the research system is changing rapidly. The main changes incorporated within the Dutch system are summarized in table 3.5.

Table 3.5: Effects of Noteworthy Changes in The Netherlands

Criteria	DLO privatization	Consolidation of Wageningen University, DLO, OARS	NRLO transformation	Creation of the WFC
Separation of financing and implementation	+			
Pluralist structure		–	+	
Focus on public goods	–			–
Public-private complementarity	+			+
Institutional autonomy	+	+		
Stakeholder participation			+	+
New models for transfer	+			+
Clear and positive legal structure		–		

Source: Developed by the authors.

The privatization of the DLO has contributed to the separation between financing and execution. Nevertheless, the execution of public-control and regulation functions may become more difficult if the DLO is committed to working with private firms that are subject to the same controls. This move facilitates the articulation between the public and the private sectors since each group can have access to scientific capacity. In addition, the degree of autonomy has certainly increased. A final

impact can be detected in the contracting mechanism that guides interaction with the DLO: the trans- fer of results is clearly more defined.

The consolidation of Wageningen University, the DLO, and the OARS under a single umbrella (WUR) appears to have few positive effects as measured by the defined criteria. The structure becomes less pluralistic and the legal regime is confusing. What is achieved is that the autonomy of the research system is increased, as is the critical mass and the negotiating power of the consolidated entity. Nevertheless, it is not clear whether this will be an advantage for the LNV in terms of the implementation of its policies since, in the long term, the WUR is likely to grow in size and importance, and it may be more difficult for the Ministry to influence it.

The NRLO has been transformed in recognition of the need for pluralism and the need to permit stakeholder interaction in the orientation of future research. The most important impact of the NRLO transformation is the development of a long-term perspective.

Finally, the creation of the WFC permits complementarity between the public and the private sectors, but, at the same time, it causes confusion in the focus given to public-research products. It also permits the participation of certain stakeholders (the food industry) in research implementation and it facilitates the transformation of basic knowledge into concrete technologies through pre-competitive research.

Nevertheless, it appears that the changes observed in the Dutch system do not just respond to efforts to better define public and private roles, as can be seen in table 3.5. There are also effects on the system's technical orientation and on its intellectual quality. Additional considerations include:

1. In the Netherlands, further increases in agricultural production are not very desirable from a social and environmental standpoint. Dutch consumers are now more concerned with environmental conservation and food safety and increasingly select products based on processing characteristics rather than price.
2. The research system can make its maximum contribution to the sustainable development of the agricultural sector and rural areas by generating knowledge, rather than by developing technologies. If this knowledge is to be converted into technologies, others with practical experience must interpret and apply the research results. Emphasis has been given to creating a system that is open enough to permit agricultural-sector stakeholders to increase their access to the results. In this respect, the privatization of the DLO, which permits contracts with other parties and the use of its capacity for public and private purposes, represents a big step forward. Nevertheless, privatization can create problems given that the same institute is involved in the generation of private knowledge on one hand (for example to develop a vaccine) and public knowledge on the other (for example, researching whether this vaccine has negative animal-health consequences);
2. The system needs to prepare itself for a more competitive future in which only a few large organizations will have a significant role. The desire to create a competitive research system is the essence of the changes now taking place in the Netherlands and reflects thinking that is broadly shared within Dutch society: for a small country, being competitive is the key to welfare. This vision of scientific competitiveness carries two sizeable risks: (1) other countries may not adopt a similar perspective and may continue to protect their research systems, so that the Dutch system remains alone in this innovation (as regards meeting private-sector demand, this is less risky); and (2) it may prove difficult to combine public functions (regulation) and private functions (generation of competitive knowledge);
3. Finally, there is a certain ambiguity in the LNV's general objectives. On one hand, it has determined that private competitiveness is the responsibility of private actors and that the public role lies in the generation and diffusion of basic knowledge, environmental management, and regulation (environmental and consumer protection). On the other hand, the LNV stimulates programs between the private and the public sector to increase competitiveness (in chain management, food technology, etc.). The conclusion is that the Dutch government considers

that the creation of comparative advantage is one of its functions; it seems that this consideration is foremost in the theories about public and private responsibilities and prevails in the definition of policies. The concept of public responsibility has been especially used to reduce the role of the government in certain activities that seem to have little economic potential and little social viability.

3.4 The United Kingdom of Great Britain and Northern Ireland

The UK is composed of a group of islands, of which Great Britain is the most important. Great Britain has three regions or political units: England, Wales, and Scotland. Another important part of the UK is Northern Ireland, which is located on another island. The UK has a population of approximately 59 million inhabitants and an annual per capita income of US$ 18,500 (World Bank, 1998). The UK has a surface area of 245,000 km^2, which is moderately undulated, although large parts of Scotland and Wales are rugged and mountainous.

Over the past few centuries, the UK had an open economy. It had great colonial power and, after the colonial period, it maintained large commercial flows, exporting industrial products and importing raw materials and agricultural products. During the past 100 years, the country has largely lost its predominate position in the world market. It is a member of the European Union, which has influenced its research policies and caused internal prices of agricultural products to be frequently above those of the world market. Some 2% of its GDP comes from the agricultural sector, which employs 2% of the active population. This means that the average income from the sector is similar to that of the rest of the economy. England is the base of various large multinational corporations, for example International Chemical Industries (ICI), Unilever, British Petroleum (BP), and Wellcome.

3.4.1 Description of the research system

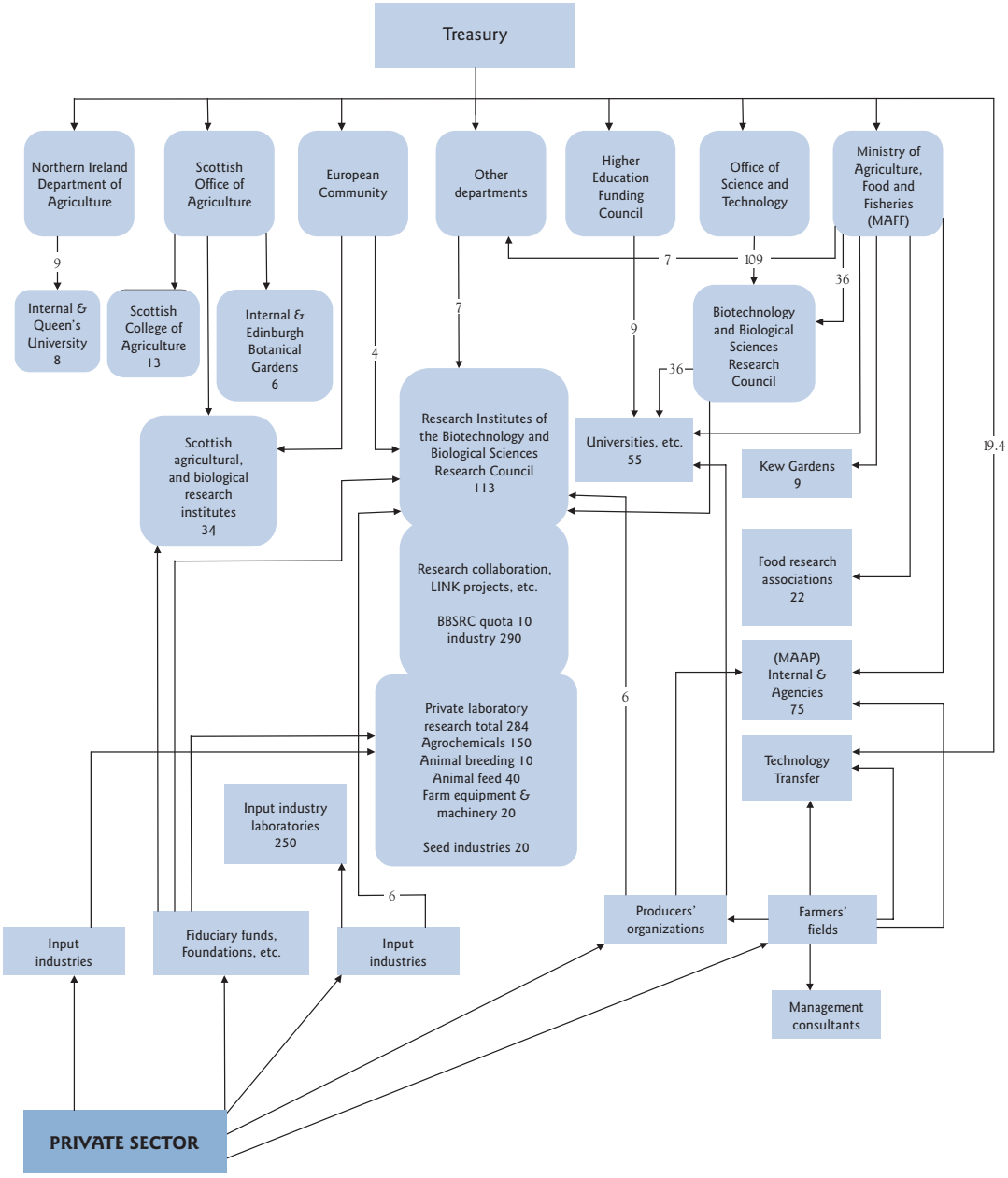
The UK's research system is large and complex. It is organized into four regions (England, Scotland, Wales, and Northern Ireland). However, not all regions have the same organization. For example, Scotland is independent, but Wales is integrated with England. Figure 3.10 summarizes the basic structure of the agricultural research system.

Financing is channeled from the Treasury to the agricultural research institutions through various intermediaries. The first is the Department of the Environment, Food and Rural Affairs (DEFRA) (formerly known as the Ministry of Agriculture, Fisheries and Food [MAFF]), which finances agricultural research in institutions that directly depend on it, such as Kew Gardens and the Food Research Associations. It also finances an applied research program within its own structure. Organized producers co-finance this program's research. In addition, DEFRA finances the Biotechnology and Biological Science Research Council (BBSRC) and university research. Total financing from DEFRA was US$ 191 million in 1994.

The second institute that finances research is the Office of Science and Technology (OST). Together with other research councils, OST finances the BBSRC for a total of US$ 167 million. While DEFRA finances adaptive, applied, and basic research, the OST concentrates on basic and strategic research.

The third source of financing is the Higher Education Funding Council (HEFC). The HEFC turns over US$ 14 million to universities for agricultural research. Other ministries contribute smaller amounts to agricultural research.

The situation is less complex in Northern Ireland and Scotland, since the majority of public funds come from public offices dealing with agriculture. Financing of agricultural research in Scotland represented around 17% and Northern Ireland represented around 3% of the UK total.



Note: The arrows indicate the principal financial flows.

Source: Modified and simplified from Thirtle et al. (1999)

Figure 3.10: Financing and organization of agricultural research in the UK, 1994 (financial values approx £ million)

There are two interesting aspects of the UK's agricultural research financing structure. First, DEFRA can assign funds to a range of activities from basic to adaptive research. Therefore, the Ministry can assign funds wherever it considers that the effect on the agricultural sector will be greatest. Second, there is competition between the BBSRC and other nonagricultural research councils. In this manner, basic and applied agricultural research compete with other types of research and need to maintain their scientific quality.

The UK also has a very large private agricultural research component. It is estimated that the agricultural input industry has research expenditures of around US$ 430 million per year (1994), and the food industry spends about US$ 380 million on research. The majority is carried out in facilities that belong to the industries themselves.

The implementation of public agricultural research is centralized in England in three types of institutes: (1) the four internal research agencies pertaining to DEFRA that focus on applied and adaptive agricultural research (with a total budget of US$ 115 million); (2) the seven institutes belonging to the BBSRC that work on basic and strategic research (with a total budget of US$ 173 million); and (3) a number of universities working on basic research (with a total budget of US$ 84 million). The implementation structure in Scotland is part of this model but its scale is smaller, whereas in Northern Ireland, there are no institutes similar to the BBSRC. A point to note is that basic and strategic research are of greater importance than applied and adaptive research. The relationship between the two groups reflects the orientation of basic research as a public good, whereas applied and adaptive research tend to produce technologies of interest to the private sector.

In 1994, the total volume of public financing for agricultural research was around US$ 475 million and that of private financing, including both agricultural and food research, was around US$ 927 million. Interaction between the public and the private sectors has been minimal, although there is a collaborative research component in the LINK[3] projects, which have a public budget of US$ 15 million. The importance of LINK is small in comparison with the total expenditures on private or public research. Data from Thirtle et al. (1999) shows that total public research financed through private funds was US$ 73 million. Another US$ 31 million came from producers' organizations (in general, branch or chain organizations), and US$ 30 million came from the sale of services by DEFRA-funded research. The sale of services, rather than the collaborative projects, saw the highest growth in financing over the past couple of years.

The position of the BBSRC in the UK's system should be highlighted. The BBSRC functions as a financier for university research and, at the same time, has an implementing role through its own institutes. Over the past decade, this combination of roles has not proven favorable for its own institutions; nevertheless, BBSRC university financing has increased.

The UK system has been highly complex for a long time and, in certain periods, this complexity has been even greater than it is now. The complexity reflects the long history and strong traditions of the public sector and of agricultural research, as well as new ideas about public-sector functions. The UK situation is a good example of how structure can affect the viability of institutions and the direction of changes.

Defining clear objectives is difficult within a system of such complexity. Support for agricultural policy is an important criterion in the research directed by DEFRA. Food quality and nutrition, as well as the compatibility between agriculture and the environment, are important within the BBSRC institutes. In general, increasing productivity within the agricultural sector has become less of a priority. The absence of clear objectives is due, to a certain extent, to the emphasis that the government has

[3] The Link program was established in 1987 to encourage collaboration between the private and the public sector. The program subsidizes projects that will be undertaken jointly by public and private organizations.

placed on the implementation of the research system. The system tends to pursue the variable objectives of other agents (especially those financing the research).

The absence of clear objectives and frameworks is also due to the fact that, over the past 25 years, there has been an emphasis on redefining public and private roles. The concern for the system's functioning has reduced the attention given to discussions about its orientation. The UK's experience tends to suggest that it can be difficult to find a balance between "doing things in the proper form" and "doing things correctly." It also seems to show that, in a system with a complex structure, the implementation of new policy guidelines can be difficult. Institutions find ways to avoid change, or they create the appearance of change while in reality the changes are modest.

A third reason for the absence of clear objectives is the presence of sponsors with very different mandates. Whereas DEFRA focuses on the development and management of the agricultural sector, OST is mainly concerned with the development of the country's scientific infrastructure. Such a combination of sponsors represents one of the basic dilemmas for every agricultural research system. The fact that financial flows are mixed is a favorable sign, indicating that the two mandates are understood.

3.4.2 Trends in public and private financing

In 1994, about US$ 475 million (current dollars) was available in public financing for the UK research system. The UK's public system has experienced irregular financing, due partly to the discussions about public and private roles. Financing declined during the mid-1980s, but real expenditures have since returned to their previous levels. Figure 3.11 shows total public financing, and the sources of this financing, in England and Wales from 1980 to 1994, a period for which exact data exists.

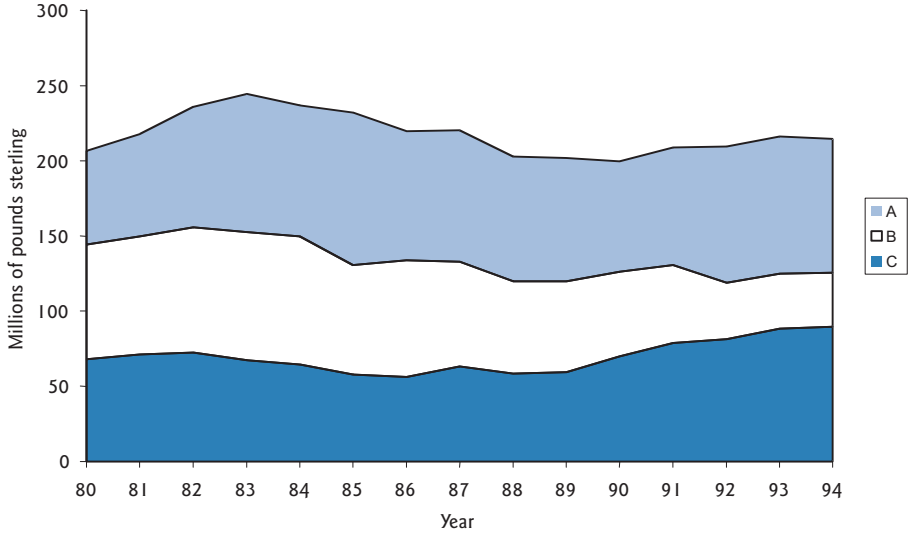
Total levels of financing have seen little change, but the relative importance of different sources has changed. The BBSRC played a large role in resource allocation at the beginning of the period, but in the first half of the 1980s, the BBSRC's direct allocation of funds was reduced, with more funds coming from MAFF. This trend reflected the implementation of the principle formulated by the Rothschild Commission in 1971, that "the client expresses the demand; the contractor satisfies it; the client pays."

Toward the end of the period, the Rothschild Commission's principle was complemented by another: "The public sector should not be involved in market activities or in those with a commercial character." As a consequence, the BBSRC once again began to allocate the majority of its resources to basic research and to the client-contractor relationship, which weakened its relation with MAFF and increased support to its own agricultural policy-related research. The Ministry wanted to reduce its technical research, but the emergence of certain major problems (e.g., mad cow disease and salmonella) did not permit this to occur. As a consequence, the level of total financing remained more stable than would have been expected given the profound changes occurring in public policies.

Total financing has reduced with respect to Gross Agricultural Product. Certain clear changes can be observed within the system with respect to the emphasis on basic research, university research, and research based on biotechnological techniques (expressed in the BBSRC's name). Applied research in support of agricultural policy is another component that has gained importance.

3.4.3 Changes in the research context

Technological demands. Major shifts in expectations have occurred with respect to the agricultural research system. The UK is a very industrialized country, in which the agricultural sector employs only 2% of the active population. Nevertheless, agriculture has a strong political lobby, due partly to



A: Ministry of Agriculture financing for its own agencies
B: Ministry of Agricultural financing for the BBSRC
C: OST financing for the BBSRC

Source: Thirtle et al. 1999

Figure 3.11: Principal sources of public financing for agricultural research in England and Wales, 1980–94

general concern for the countryside and rural life, and partly to the traditional rural roots of the aristocracy. Even before the Second World War, the UK imported food from the Americas and its ex-colonies to feed the industrial workforce. The war highlighted the vulnerability of this food supply and compelled the country to implement a policy oriented toward agricultural self-sufficiency. The modern technologies and inputs required to achieve self-sufficiency encouraged agricultural research toward greater productivity. Subsidies were accepted by the public and, as a consequence, the UK attained self-sufficiency in various important products.

Public attitudes toward the agricultural sector began to change during the 1970s. Memories of food shortages during and after the war faded, and integration into the European Union changed opinions about the need for national self-sufficiency. Agricultural price subsidies became less acceptable, and environmental concerns increased because subsidies induced intensive production patterns that did not respect the environment (e.g., destruction of hedges, high use of agrochemicals), or animal welfare (large-scale intensive pig, poultry, and cattle production). Public opinion has inclined toward rejecting financial and technological support for a sector that has a large segment of wealthy farmers who, increasingly, seem to have lost respect for the environment and have adopted industrial-type production technologies. Reality in the agricultural sector is probably not so bleak as public opinion paints it; many farmers respect the environment and their animals, but perceptions strongly influence the policies adopted (Roberts 1999).

Adverse perceptions have been reinforced by problems with salmonella, mad cow disease and its association with Creutzfeld-Jacob disease (fatal to humans), and the concern with the environmental and health effects of genetic modification. Discussion surrounding these problems is emotionally charged and has contributed to the idea that new agricultural technologies are artificial and dangerous.

Public demand is inclining toward organic foods (as in Switzerland) that are perceived to be safer and that use natural environmental management methods. The public has little interest in financing research that results in greater productivity and greater incomes for actors in the agricultural sector.

Changes in the organization of science and research. The UK was one of the first countries to formally recognize the existence of scientific supply and demand and, in the 1980s, it attempted to organize research according to this principle. This resulted in a growing separation between financing and implementation (Beattie 1998). Basic research was exempt from this principal but, even so, financing decisions have been separated from implementation.

A second change in scientific organization has been the incorporation of the UK into the European Community, which has given the UK system a broader range of possibilities for collaboration and an additional source of financing. This integration has been one of the factors that contributed to the increasing importance of research projects implemented with partners from other countries.

A third change is the growing competition between BBSRC institutes and universities in the search for research funds. The recognition of supply and demand in research has also resulted in the application of strategies to obtain access to more and different types of funds. The universities have more experience in contacting and accessing different financing sources than do the BBSRC institutes, since the latter depended more exclusively on the BBSRC only.

In terms of research topics, the UK system has been very active in the development and use of biotechnology and the name of the BBSRC (Biotechnology and Biological Sciences Research Council) reflects this emphasis. Before 1994, the Agriculture and Food Research Council (AFRC) worked together with the BBSRC. The consolidation of the AFRC within the BBSRC indicates the importance of biotechnology. The fact that the word agriculture does not appear in the name of the institute also indicates that the sectoral limits to research are disappearing.

Public and private responsibilities. The UK has experienced considerable evolution in the definition of public and private responsibilities. The first important change was the establishment of the client-contractor principle by the Rothschild Commission. The principle has greatly helped define research priorities (the responsibility lies with the client and not with the researcher), and research evaluation (the client, and not the researcher, is to be satisfied). Nevertheless, this principle also has various limits such as transaction costs, a lack of continuity, stability, and flexibility, and the development of strict relations between client and contractor that reduces the desired transparency and clarity.

The most important changes have occurred since the election of Margaret Thatcher as Prime Minister in 1979. She promoted a very ambitious program to redefine the role of the public sector. The most important justifications for this program were the government budget deficits and the decline in the national economy that were held to be due to the past government's high rates of public spending. In the Thatcher government's vision, public research would have to be reoriented toward productivity increase and technology transfer, where the beneficiaries are clear and mechanisms can be established to encourage the beneficiaries to take the responsibility for research. The relevance of public research for increasing productivity decreased even further due to European agricultural surpluses.

According to these criteria, public research would have to be concentrated on public topics (for example, support for economic policies, environmental management, and consumer protection) or on basic research, and the allocation of contracts would have to be based on competitive procedures, thereby creating a quasi-market (where prices are defined in a similar way as in a market arrangement). To achieve these effects, follow-up and evaluation procedures were reinforced.

The Thatcher government argued that the agricultural sector was made up of many small producers, each incapable of financing a research program. It reasoned that there were sufficient possibilities for producers to organize themselves and establish mechanisms to finance their own research, for example through surcharges. Wherever possible, research with direct producer benefits would be financed through statutory organizations, which had the right to impose surcharges. This form of financing has increased in importance, although at a slower rate than had been planned due to objections on the part of the European Union, which considered that some of the statutory organizations had monopolistic objectives. In 1994, statutory organizations mobilized only US$ 31 million, and the government continued to develop new organizations.

Another argument that was not accepted by the Thatcher government considered that consumers were the principal beneficiaries of higher productivity. The rationale was that the UK was integrated into the European Community and that, with free food markets, national consumer prices were no longer dependent on the results of national research. Therefore, the majority of the benefits of national research would go to producers, thereby increasing their incentives to finance research.

It is important to understand that the changes forthcoming from the Thatcher government, and the subsequent Major government, were not specifically directed at public research. On the contrary, public research experienced the same processes as the rest of the public sector. What is interesting to observe is that the objective of creating greater competitiveness and more favorable market conditions within agricultural research has possibly been obtained, but there has been little reduction in the public budget for agricultural research; only a control of expenditure.

3.4.4 Responses and institutional innovations

Governance. MAFF/DEFRA and OST have sponsored the UK system since 1918. Over the last 15 years, the importance of OST has increased (see figure 3.10) along with a growing emphasis on basic research which is considered to be a public good. Research within DEFRA is directed more toward the support of its own activities and toward research at the service of producers who co-finance or completely pay for the costs of these services.

For a long while, the UK system has had a certain degree of decentralization, especially with respect to agricultural research in Scotland. The developments of the past 15 years have had little impact in this sense. Important changes have occurred in the growing separation between policies, financing, and implementation. The government has taken on a more active role in defining policies, which were previously determined mostly within research institutions. Additional mechanisms have been established for funding allocation. The central task of the BBSRC was to separate its roles as financier and executor. Apparently, at present, the separation has been achieved. Nevertheless, it is not known what degree of success will be obtained if the two functions remain within the same organization.

The role of producers in system governance has not increased and, with the client-contractor principle, it has been defined as a function of the financing that they contribute: producers control the contracted research whereas the government controls research carried out with public funding.

In some research institutes where results can be easily marketed, the government decided not to increase producer financing, but rather to sell these institutes to industry. This happened to the Plant Breeding Institute, which was sold to Unilever. Obviously, a great change in the institute's orientation followed. The institute in charge of horticultural research was transferred to the British Horticultural Society and now obtains its financing solely through contracts and competitive funds.

The UK has placed much emphasis on the establishment of more formal procedures for research evaluation. This topic is treated in greater detail in section 3.4.5.

Financing. The emphasis on competitive funds has greatly increased. The BBSRC finances basic research in universities to a value of US$ 55 million per year, mainly through competitive funds. Part of the financing for the BBSRC institutes also comes from competitive funds, although the actual amount is not clear.

Cofinancing provided by producers is made difficult due to legal problems faced by traditional branch organizations (e.g., marketing boards) within the European Community framework. In the mid-1990s, the government reestablished Development Councils for different products with the right to impose surcharges for research financing and other functions. However, these do not operate through cofinancing, but instead pay in full for their research needs.

The UK system, with its different clients and suppliers, has placed much emphasis on contracts. For example, DEFRA contracts the BBSRC to the amount of US$ 55 million and the universities to the amount of US$ 15 million. The support for contracts is related to the client-contractor principle in which the separation of financing and implementation occurs.

Research implementation. International research has been very important in the UK, due mainly to European Community financing, which is oriented toward cooperation between countries (most projects require partners in three or more countries). Although the volumes are not large (US$ 4 million in 1998), the effects are substantial. In addition, the UK maintains an international research program with developing countries, involving mainly collaborative research between British universities and developing country institutions. This research is of an applied nature.

The LINK program was established to promote collaboration between the public and the private sectors. However, the public funds invested in the program are rather low (around US$ 15 million per year). It is not surprising that the concept of collaboration between the public and the private sectors conflicts with the principles of public sector reorganization. However, Roberts (1999) wrote that the LINK program has been effective and has influenced knowledge transfer. Aside from the producer organizations that allocate some US$ 30 million to public research institutes, agroindustry spends some US$ 45 million on research in public institutes. It seems that industry has more interest in having access to public sector scientific capacity than in engaging in collaborative projects.

Agricultural research in England has been increasingly directed toward basic topics and support for public functions, such as agricultural policy and environmental protection. Research infrastructure has also been rationalized in this change process: the 18 institutes supported principally by OST (through the BBSRC) have been reduced to eight.

The last point to emphasize regarding research implementation is the increase in short-term employment contracts. Research contracts obtained through competitive funds do not permit long-term labor contracts to be established and therefore reduce continuity in the research system. The advantage is that many ex-scientists apply their knowledge in other places; the disadvantage is that knowledge and experience are lost and it is difficult to attract the best professionals into agricultural research.

3.4.5 Noteworthy initiatives

Efforts to redefine public and private research roles. The first steps were taken in 1972 when the principle of "the client expresses the demand; the contractor satisfies it; the client pays" was accepted. This separated implementation from research policy definition, and research program definition from implementation. It was recognized that there was no equivalent principle available for defining relationships in basic research.

The establishment of profitable prices for laboratory services supplied by research institutes, which occurred in 1979, was a logical consequence of the application of this principle. Another step was the free contracting of research services throughout the research system. Free contracting deepens the client-contractor principle, and creates distance between the public organizations demanding research and the research organizations themselves. Frequently, various institutes were invited to submit research projects that were then awarded to the best provider. This allowed the councils (such as the BBSRC) to become independent from the institutes.

The costs of the changes have been high in terms of the lack of continuity and growing transaction costs within the system. It is not clear whether all of the changes contribute to establishing a scientific system that creates wealth and welfare, mainly because continuity is in question. The impacts on public financing seem to have been minimal and the stimulus provided to the private sector is not very evident. From another standpoint, the changes have permitted priorities to be established that are more relevant to current needs and they have also contributed to a greater emphasis on basic research.

Attention to basic research in universities. Traditionally, universities played a limited role in research, but their contributions have increased over the years. In a certain sense, the shift of funding from the more applied-research-oriented institutes towards the more basic-research-oriented universities secured funding that would otherwise have been questioned. From another point of view, universities can adapt their research agendas with greater flexibility. As a consequence, public research carried out in universities increased from 2.9% in 1981 to 14.7% in 1993. Nevertheless, this figure is low in comparison with the USA, the Netherlands, and Switzerland.

The UK has expressed concern for the low impact of the scientific system on societal development and, therefore, it is worthwhile reviewing the role of basic research in this respect. The Political Science Department at the University of Sussex, in a study commissioned by the Treasury, observed that basic research leads to six major benefits:

- new information;
- new instruments and technologies;
- increased capacity among researchers and especially among postgraduate students who later move on to other activities;
- access to networks of experts and information;
- ability to resolve technologically complex problems;
- creation of new companies based on new discoveries.

This list shows that technological results form only a small part of overall research benefits and that, to obtain maximum benefits, it can be very useful to have a link with the university environment.

A step that would facilitate agricultural research in universities is the establishment of an evaluation mechanism, such that the relevant university institutes would be evaluated every five years in an exercise that would also define the institutes' financing for the next five years. This kind of mechanism seems to be highly effective for managing basic research. Unlike competitive funding, it is not particularly suitable for low-risk projects.

Changes in research orientation. Since 1984, food research has become much more important. The decisive step was the inclusion of the food industry in the (precursor of the) BBSRC, which was then extended to include the retail sector as well. These inclusions corresponded to the adoption of a chain focus. In 1989, food research totaled 15% of the budget of the (precursor of the) BBSRC.

Since the UK entered the European Community, agricultural production has increased in response to high Community prices. This intensification has caused pollution and environmental degradation and public opinion has encouraged the research system to reduce its emphasis on productivity and replace it with the concept of sustainable production that does not pollute or damage the environ-

ment. Of the eight institutes under the umbrella of the BBSRC, one is solely dedicated to these topics. It was not possible to determine which of the other institutes' activities are related to environmental issues.

3.4.6 Conclusions

The UK has a sophisticated system with a long history. It has diverse actors and types of organization and, therefore, should be capable of absorbing the majority of the changes in orientation recently introduced into the system. The new basic research system places greater emphasis on universities and has reduced near-market research in the BBSRC institutes.

Table 3.6 summarizes the effects of the principal changes in the British system. As Roberts (1999) explains, the effects of individual changes on individual criteria are, in general, positive. The redefinition of public and private roles has contributed to greater conformity with the expressed criteria. The exception to this is found in the criteria of "stakeholder participation." The effort to separate public and private roles appears to have diminished the participation of stakeholders. The attention paid to basic research was, to a certain degree, a consequence of these changes, since basic research is considered to be a public good. Basic research will also benefit from new transfer mechanisms. Emphasizing research within universities makes the most of independent locations and confers greater research protection, while the universities, in general, have greater autonomy, especially in how they use funds. The changes in the orientation of research toward environmental and food safety topics show that the system has been able to react to new demands, and has facilitated new management mechanisms and increased the level of basic knowledge.

Table 3.6: Effects of Noteworthy Changes in the UK

Criteria	Redefinition of public and private roles	Attention to basic research in universities	Changes in research orientation
Separation between financing and implementation	+	+	
Pluralist structure		+	+
Focus on public goods		+	
Public-private complementarity	+		+
Institutional autonomy			
Stakeholder participation	–	–	+
New transfer models	+	–	
Clear and positive legal structure	+		

Source: Developed by the authors.

Nevertheless, Roberts (1999) also observes that the total effects of the changes have been less marked than the partial effects. The sophistication of the system creates its own interactive process. For example, the budget reductions imposed by the Thatcher government were not achieved, since when funds were reduced in one area, they re-appeared in another.

The question remains whether the new management mechanisms have achieved greater efficiency or have just resulted in more bureaucracy. In this respect, motivational changes should be compared with organizational changes. Apparently, many researchers feel that their ability to develop long-term plans is very restricted, and they attribute this to a lack of confidence within the system. As Roberts (1999) says, the system suffers from a "management syndrome." While previously there was

liberty and individual responsibility with little orientation and control, the current system is characterized by stringent control and orientation, with less liberty and responsibility. The relevance might be improved in the short-term, but the effects cannot be foreseen over the long-term. Concern remains over employment instability, the difficulty of contracting the best personnel, and the absence of resources for exploratory research.

One of the major consequences of the changes is the disappearance of strategic research. In the definition of roles, basic research is considered to be a public good and a public responsibility, and adaptive and applied research are carried out under contract. Nevertheless, there is almost no attention to the gray area in between, in which the application of basic concepts is studied. As Spedding said, as early as 1984, when the changes began, there was very little real agricultural research!

This problem does not occur in environmental and food-safety research, since the entire topic is considered to be of public interest, and the spectrum that extends from basic to adaptive research is therefore a public responsibility. The result is that public research attempts to maintain the knowledge base and investigate the collateral effects of agricultural activities. The value of the funds that are managed indicates that society is greatly concerned with the impacts of the agricultural sector on human welfare.

The rate of change has been very rapid and the changes have been so broad that it is difficult to interpret the overall effects. In some ways, this reflects the ideological nature of the changes that took place, not just in agriculture but throughout British society. Changes responded less to a diagnosis of what was wrong with the research system and more to an ideological blueprint of how society ought to be organized. Therefore, it is difficult to know if the problems of the past have been overcome. What does become clear is that the costs of managing the system have increased owing to the proliferation of management levels and procedures, and higher transaction costs. Roberts (1999) suggests that the space for single-mindedness, creativity, and serendipity, which are also necessary for research, may have been lost. His conclusion is that the changes have concentrated on the management of the research system as a structural entity. Without denying the importance of this aspect, his criticism is that the most important resource in the system—scientific personnel—has been neglected.

3.5 Switzerland

Switzerland is a relative small and isolated country. It has around seven million inhabitants in an area of 41,000 km^2, which is dominated by high mountains. Per capita income is very high, at around US$ 38,000 in the mid-1990s (World Bank, 1998). Switzerland has no sea access. Although not a member of the European Community itself, it is surrounded by member countries. It is the base of some powerful multinational agroindustries such as Novartis and Nestlé. Around 4% of the active population work in the agricultural sector. The participation of the agricultural sector in GDP is around 2.1%. Internal prices are often above world market prices.

3.5.1 Description of the research system

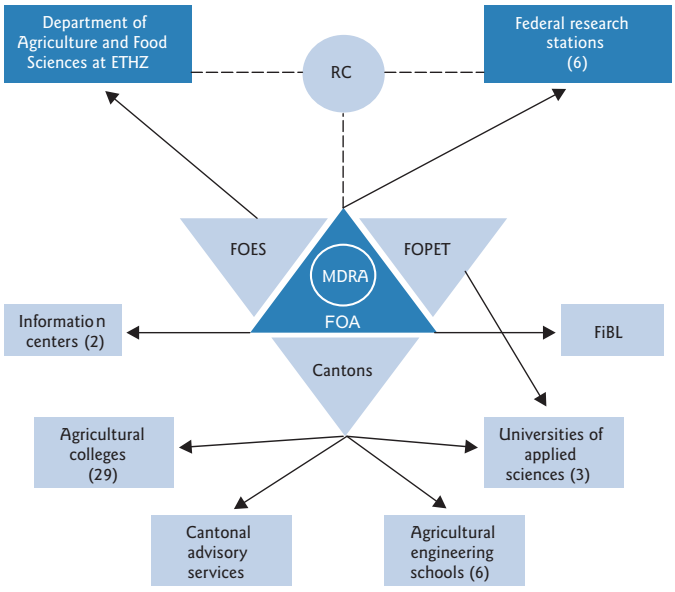
There are two main components of public-sector agricultural research: (1) the Swiss Federal Institute of Technology-Zurich (ETHZ), responsible for basic research; and (2) the network of institutions reporting to the Federal Office of Agriculture (FOA), responsible for applied research. The ETHZ has a budget of US$ 25 million, 29% of which stems from nonfederal sources. Zero growth is expected in the federal contribution to this budget. ETHZ's funds are provided by the Federal Office of Education and Science (FOES). The research institutes reporting to the FOA manage the remainder, which is 73% of the total. The federal government planned to reduce its contributions to the applied research institutes by 25% over 2000–02.

In addition to the ETHZ and the Federal Institutes, there are other, less important, components: (1) the Research Institute of Organic Agriculture (FiBL), which was established as a private foundation but obtains the majority of its funds from federal sources; and (2) the faculties of Veterinary Medicine, the university departments of Geology and Forestry Sciences, and the Federal Institute of Environmental Science and Technology.

In 1996, the Council for Agricultural Research was established with the purpose of coordinating the different federal offices' research efforts. One of the Council's concrete objectives is to ensure that the ETHZ concentrates on basic research while the other Federal Institutes concentrate on applied research.

The Swiss research system is linked to two information centers that provide practical information to producers, to private extension services and to canton (state) services. In addition, the links between the system and the universities in the area of applied sciences that were established at the beginning of the decade are being strengthened. Figure 3.12 summarizes the basic structure of the Swiss system.

The Swiss system has three interrelated objectives: (1) to improve economic efficiency; (2) to increase environmental compatibility; and (3) to ensure nutritional quality. Environmental compatibility is the principal objective of the Federal Institutes, whereas nutritional quality is more important in ETHZ. The objectives directly reflect the multifunctional character of Swiss agriculture. In addition, they reflect the position that the Swiss government has adopted since 1988, that agricultural research is not an instrument to meet the interests of a specific group (farmers), but rather to serve the needs and demands of society as a whole.



The arrows indicate the principal financial flows. The entities in gray are the main components of the Swiss system.
FOA: Federal Office of Agriculture/ FOES: Federal Office of Education and Science / FOPET: Federal Office for Professional Education and Technology / MDRA: Principal Division for Research and Extension (in the FOA) / RC: Research Council / FiBL: Research Institute of Organic Agriculture / ETHZ: Swiss Federal Institute of Technology-Zurich

Source: Baur and Rieder (1999).

Figure 3.12: Basic structure of the Swiss national agricultural research system

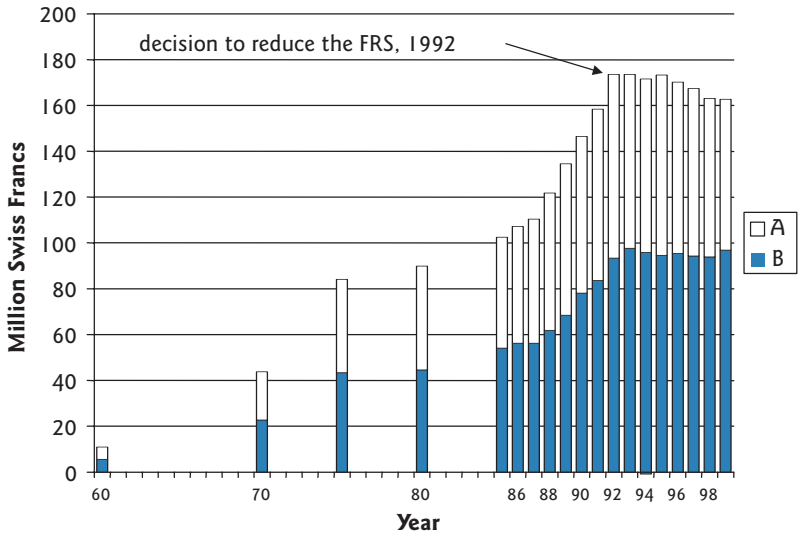
3.5.2 Trends in public and private financing

In 1996, public research expenditures were in the order of 140 million Swiss Francs, equal to some US$ 100 million (Swiss Federal Office for Agriculture 1998), which corresponds to 1.8% of the agricultural GDP. Private research expenditure is more difficult to estimate since large industries are not obliged to publish this data. In 1993, it was estimated that private research expenditures were around 50% higher than public research expenditures (ISNAR internal data). Nevertheless, in 1998, Baur and Rieder (1999) calculated that Novartis spent US$ 480 million and Nestlé US$ 525 million in agribusiness research, obviously to support their worldwide activities. The interaction between the public and the private system has decreased over the past few years.

Figure 3.13 shows the development of expenditures of the Federal Agricultural Research Stations that are financed by the FOA. It can be observed that, after a period of rapid growth in the 1980s, the level of financing has stabilized with a tendency toward reduction, and more budget reductions are expected in the future. In 2001, the research expenditures of the FOA will have reduced by 25% compared to 1993.

To achieve a reduction in the federal contribution, attention to public goods had to be increased and responsibilities for other activities had to be transferred to the private sector. In addition, management within the federal institutes is changing toward a system of "new public management" that emphasizes research through projects with clear objectives, fixed implementation periods, and evaluation of results.

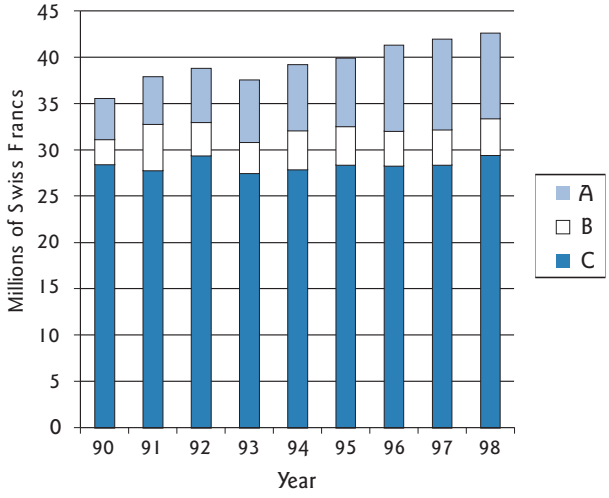
Basic research in the Department of Agriculture and Food Sciences of ETHZ has not suffered from budget cuts. As can be seen in figure 3.14, its budget gradually increased over the last decade, due mostly to opportunities to exploit new funding sources (contracts with the private sector and other governmental entities).



A: Education/Extension
B: Research

Source: Baur and Rieder (1999)

Figure 3.13: Federal expenditures on agricultural research in federal institutes, plus expenditures on education and extension services, Switzerland, 1960–98 (operation costs only)



A: other funds
B: other federal funds
C: regular federal funds

Source: Baur and Rieder 1999

Figure 3.14: Development of funding at the Department of Agriculture and Food Sciences of the ETHZ, 1990-1998

3.5.3 Changes in the research context

Technological demands. After the Second World War (in which Switzerland was neutral and isolated in the middle of occupied and aggressor countries), food productivity and security became important objectives for agricultural research. In the mid-1980s, the Swiss system's emphasis changed rapidly from an emphasis on agricultural productivity to environmental compatibility. Problems such as water pollution, soil contamination by heavy metals, loss of biodiversity, and vulnerability of mountain slopes have contributed to this change in emphasis. The main objective of environmental conservation is accompanied by secondary objectives such as improvement of agricultural sector economic performance. Agroindustrial demands are emphasized in basic research but at an applied level, the same industries are responsible for responding to these demands. The demand for research services to define agricultural policies, environmental legislation, and consumer protection has increased a great deal. In fact, a large proportion of applied research in the Federal Institutes is directed toward these goals.

Changes in the organization of science and research. Basic research has been affected markedly by the growth of biotechnology. Research in agroecology is also receiving growing attention. Through a referendum, the Swiss population had the opportunity to vote on a proposal in which biotechnological research would have been heavily restricted. Although the referendum was rejected, the fact that it was held illustrates the scale of public skepticism in Switzerland about genetic engineering. The recent refusal by the Swiss government to approve ETHZ field tests of genetically modified wheat has to be seen in this light.

The links between applied research and agricultural policy have been reinforced. Applied research was increasingly directed toward an agenda defined by the FOA. Another change in research organization at the applied level is that the special institute that researched environmental topics has been closed. Instead, it was decided that each institute should have a strong focus on environmental aspects.

Switzerland is aware of the importance of international collaboration. First, it considers this as a means to enter into and participate in broader scientific networks and, to stimulate this type of collaboration, Switzerland is negotiating treaties with the European Community to permit Swiss scientists to participate in European Community programs. Second, Switzerland has acknowledged that the process of sharing scientific knowledge with the global agricultural community is in the interest of its population. It has established the Swiss Center for International Agriculture (ZIL) to strengthen its participation in the CGIAR and in developing countries.

Public and private responsibilities. There are three aspects of note in this area:

1. The allocation of responsibilities between the public and the "conglomerate" private sectors appears to have changed little. The public sector has never been responsible for the type of applied research that leads to rapid benefits for multinational conglomerates. Contacts between the Federal Institutes and the agroindustrial sector are few. Nevertheless, at the level of basic research (ETHZ), there are many interactions through research contracts;
2. Agricultural research responsibility toward producers has changed a great deal over the last 20 years. The attitude toward producers has changed markedly with the acceptance of the principle: "Agricultural research is not an instrument to meet the interests of a specific group (farmers), but should serve the needs and demands of the entire society." Applied research is directed at creating standards and laws to control rather than support the producer. The environmental and social effects of agricultural production are of greater concern to Swiss citizens than an increase in the welfare of producers through research.
3. Since the beginning of the 1990s, the Swiss government has been facing large budget deficits. These have had a large impact on the level of research financing and have contributed to the revision of research objectives. Another consequence is that the government is reviewing its forms of management. It has adopted the principles of "new public management" throughout the public sector, giving greater emphasis to defining objectives and evaluation indicators for the different units and projects. The budget deficit is also causing the FOA to exercise greater influence over the use of resources within the Federal Institutes, which is reducing their freedom to make decisions. The budgetary problems are one of the main factors that have contributed to the ongoing changes.

3.5.4 Responses and institutional innovations

Governance. The Swiss system has been focusing on finding solutions for its financial problems. The relative freedom of the Federal Institutes has been reduced and the mission and competitiveness of each institute has been defined at the higher national level. The interaction has intensified between the FOES and the FOA, the two offices with responsibility for supervising the NARS in terms of strategic agricultural research planning. In addition, a new Research Council was formed with responsibility for system orientation (see section 3.5.5). The role of producers in system governance is very limited; this is the responsibility of public offices reinforced by scientific experts and representatives of the organizations involved in environmental research and policy. Nevertheless, farmers have had and continue to have political influence that in general is disproportionately high with respect to the general population.

The autonomy of the Federal Institutes has been reduced over the last 10 years as a consequence of fiscal problems and the desire for the institutes to concentrate on public technological demands. This has not been the case for basic research, but the need to seek funds from other sources (given the stable government budget in this area) could have effectively reduced autonomy in this sector. Privatization efforts are not part of this scenario and have not been in evidence. Finally, it can be observed that evaluation systems and mechanisms have been strengthened in response to new public management needs.

Financing. Traditional financing mechanisms are used within the public sector with funds assigned to different entities rather than to work programs or outputs. There are no competitive mechanisms (they would not be very effective in a small country), nor are shared funding mechanisms (matching grants) or surcharges used to finance research. The management of the financial system is relatively simple.

Research implementation. Two changes are occurring in research implementation methods. First, Switzerland is attempting to participate more actively in international research. Agreements have been made with the European Community to allow the country to participate in its tenders and programs. In addition, the Swiss Center for International Agriculture was established in 1993, and contributes to strengthening the links with the CGIAR and developing countries. The second change is the integration of newly established Applied Science Universities into applied research carried out within the Federal Institutes. This is explained in more detail in section 3.5.5.

3.5.5 Noteworthy initiatives

Research Institute of Organic Agriculture. The establishment of this Institute is the most obvious sign of the importance given to compatibility between agriculture and the environment. The Institute was established as a private foundation in 1973. In recognition of the importance of the topic, the federal government has begun to cofinance the Institute, which continues to be independent and is responsible to the Foundation for its actions. With 70 permanent staff members, the federal contribution to its budget is US$ 1.4 million, which suggests that there is additional financing from NGOs.

National Research Council. This was established by the Swiss Parliament in 1993. The Council supervises both basic research in universities and applied research. It plays a mediating role between the two principal sources of financing: the FOA and the FOES. The Council was established to ensure the national relevance and applicability of research and specifically to increase the relevance of the applied research done by the FOA, since the system had been following its own directions without attending to the needs of the sector. The Council advises the FOA and the ETHZ with respect to their research strategies. It also coordinates the principal components of the system, and it evaluates the research strategies and results obtained.

Universities with mandates for applied research. To improve scientific and technical education in the country, certain engineering and higher education schools have been transformed into Universities of Applied Sciences. These universities have been seeking ways to strengthen their research activities. Financial pressure on the research system has led to introduction of a contractual framework and the applied research funded by FOA can be done in collaboration with, and in support of, the Universities of Applied Sciences. The framework improves integration between research and education in a similar way to the Land Grant system in the USA (although on a much smaller scale), or to the WUR organization in the Netherlands. Using relatively inexpensive human resources available in universities reduces the costs of research. In a manner similar to the Land Grant system, the Swiss Federal Government is partially responsible for financing the new Universities in Applied Sciences. It contributes one third, and the rest must be obtained through canton (state) or private funds. The contractual framework was established in 1997, and its operational implementation has not yet been fully tested. One complication is that universities and federal research institutes are financed from different sources and through different procedures.

3.5.6 Conclusions

Organization of the Swiss system is relatively simple. Research is based on two main entities: the ETHZ and the Federal Institutes. The integration of the Federal Institutes with the Universities of Ap-

plied Sciences has streamlined organization. The Swiss system is likely to remain small and simple due to its direct financing mechanisms. Financial pressures will ensure that the system experiences little growth.

Noteworthy changes are summarized in table 3.7. Because of these changes, the Swiss system has become more articulated and is making better use of the comparative advantages of the different participating entities. New opportunities for knowledge transfer are being created through the Universities of Applied Sciences. The system also clearly recognizes that external demands are changing and it is starting to focus on specific demands, for example, research initiatives in organic agriculture.

Table 3.7: Effects of Noteworthy Changes in Switzerland

Criteria	Research Institute of Organic Agriculture	Research Council	Universities of Applied Sciences integrated with Federal Institutes
Separation between financing and implementation			
Pluralist structure	+	+	+
Focus on public goods		+	
Public-private complementarity		+	
Institutional autonomy		–	
Stakeholder participation	+	–	
New transfer models			+
Clear and positive legal structure			

Source: Developed by the authors.

Overall, it seems that the Swiss system has not tried to separate financing and implementation, but it has reduced its expenditures through direct cuts to programs that are considered to be of secondary importance. The system is becoming somewhat more pluralistic and more directed toward international research. The public focus is clearly maintained and the complementarity between the public and the private sectors is guaranteed by the clarity of public research. However, there is limited interaction between the two sectors. Autonomy has not increased and, for a system that is suffering from budgetary pressures, this could help to ensure survival. Less autonomy can also mean less vulnerability. The participation of stakeholders in the Swiss system is limited and, looking at the composition of the Research Council, there is no tendency for it to increase.

The changes in the Swiss system stem as much from changes in agricultural policy as from changes in science policy. The most important changes have come about as a result of government budgetary problems. However, changes in the demand for technology (e.g., reflecting environmental and food safety concerns) have been observed and incorporated. The responses to fiscal problems have been varied. In basic research, contacts have been made with other financial sources (including the private sector); in applied research, the integration with the Universities of Applied Sciences could represent an effective means to increase research even with lower investments. The application of the principles of new public management is another step intended to rationalize costs. The cuts have been made with care in order to avoid panic and demoralization. The need to change is causing the system to reorient itself and to prepare for the future.

Chapter 4. Synthesis, Conclusions, and Implications

This review of developments in the organization and financing of agricultural research in developed countries and, specifically, in Australia, the USA, the Netherlands, the UK, and Switzerland, highlights certain trends. Obviously, individual events have shaped the responses in different countries and interpreting the developments requires caution and judgment. Nevertheless, the methodological framework applied throughout the case studies helps provide a synthesis that could be valid for other countries and regions.

4.1 Synthesis of developments in international research

4.1.1 Globalization

The process of globalization is forcing research and technology service suppliers that previously worked within national markets to turn to other markets. International research, for example within the CGIAR system, has had to adapt to these developments by redefining its role in the transfer of technology between countries. These adaptations will encourage greater interaction with private agricultural research and with the multinational firms that are leading the process of technology integration.

4.1.2 Environment and poverty

The international research system is influencing a shift in all public-sector research toward natural resource management and poverty reduction. This means that taxpayers are funding efforts to improve equity and agricultural sustainability, themes that are of little interest to the private sector. Interaction with NGOs is being reinforced in programs aiming to achieve these objectives.

4.1.3 Specific projects and restricted funds

Both national and regional research is increasingly being organized through projects. Financing is also obtained on a project basis, and the availability of funds for the general support of regional or international organizations is diminishing. Project financing responds to donors' needs to provide greater accountability within their own countries. Changes in financing mean that national and international donors have increasing influence on the directions of research.

4.1.4 Broadened alliances and governance

Trends for increasing collaboration with private and nongovernmental sectors are being translated into new methods of governance within international organizations. Forums (world and regional) of agricultural research stakeholders represent an effort to share influence with various nontraditional interests and to form a platform for establishing joint activities with new allies. The question is how research financiers see this broadening of governance: as an increase in relevance or as a loss of their own individual influence?

4.1.5 Consolidation

There has been little growth in the financial base of the international system. However, the importance of international and regional organizations in generating knowledge and new agricultural technology is well established and, possibly, more accepted among stakeholders than it was previously. The lack of budgetary growth can be explained by the diminishing importance of the agricultural sector in many countries. As a response, a process of consolidation is occurring. Rather than creating new initiatives, efforts are being made to consolidate under the umbrella of broader international and regional organizations. The possible advantages stemming from coordination and political strength should be balanced against the disadvantages of a growth in bureaucracy.

4.1.6 External financing

Most regional organizations continue to depend on external funds. With only a few exceptions, developed-country donors supply the required resources. This means that, in many cases, national political support for regional or international collaboration continues to be weak. Dialogue occurs, but the national purse remains closed.

4.2 Synthesis of developments in the agricultural research context

4.2.1 The status of the agricultural sector

The status of the agricultural sector has changed, especially in European countries, and also in Australia. The agricultural sector is losing a privileged position that was based on the following:

- concern for food security due to food shortages during and after the Second World War;
- respect for the role of agriculture as a guardian of nature;
- the image of a peaceful rural lifestyle.

Following the Second World War, agriculture was transformed, through technological development and commercialization, into an industrial-style sector in which food production seemed to be based more on manipulation of nature and less on respect for it. The pork sector in the Netherlands and the beef sector in the UK are clear examples. These developments have caused doubts and have affected public opinion. Since then, fears of international conflicts have decreased and the need for food security has diminished. The agricultural sector has reduced in size in comparison with the general economy.

Political support for the agricultural sector has also declined. Public agricultural research is now seen more as an instrument for sectoral guidance than support. Issues such as environmental protection, food safety, and animal welfare receive more support than topics related to productivity. The challenge for the agricultural sector within the wealthy countries is to project a balanced social and environmental attitude. This does not mean that new technologies should be rejected, but that their evaluation should be more open and responsive to public opinion.

4.2.2 Financial pressure

There has been little or no growth in public agricultural research budgets in the case-study countries. The previous discussion gives some of the reasons for this. In addition, fiscal deficits in many countries have created financial pressure on the public sector in general. At the same time, demands on the agricultural research system have changed but have not lessened, resulting in increased pressure for performance. The response has been to seek new arrangements that permit more research to be attained with less financial resources, or that permit sharing of responsibilities.

4.2.3 Emphasis on public goods

In all countries, the unique position of the agricultural sector, combined with financial pressure, has given rise to a review of public-sector research in this field. It is interesting to observe that the lack of organization among farmers, which previously was an important justification for interventions, is no longer presented as an argument in favor of research as a public good. There are sufficient opportunities for producers to finance research that serves their own interests. The public goods pursued at the moment are those defined in terms of protection of urban citizens: i.e., food safety, nature, animal welfare, water quality, etc. Basic research is a well-accepted public good and strengthens a country's "knowledge cloud." The "public-good" argument is, therefore not completely free from biased interpretation. It is worth noting that the consumer protection perspective has been very much accepted in other industries besides agriculture.

With respect to the interpretation of public good, two points of view should be noted: (1) in the USA, changes reflect a movement toward an "entrepreneurial government" that attempts to stimulate change in society and to determine its demands; and (2) the position is different in European countries: when there is a demand, there is a means to meet it through the private sector. The reduced role of governments and the modification of the juridical status of public institutions have been emphasized to permit private groups to respond to demand.

4.2.4 Attention to environment and food safety

There is a demand for new technologies that promote environmental conservation and food safety. Public agricultural research is focused on environmental protection and human welfare and the possible negative consequences of agricultural activities. This tendency is more marked in Europe than in the USA or Australia, since in the latter countries environmental impact is perceived as less of a problem, thanks to the large land area. Technological demands in these areas have an important regulatory dimension, for example, what are the permitted norms in terms of animal waste products? What are the norms for food composition? Another area of concern relates to policy: how can use of water resources be optimized? How can incentives be created for sustainable resource use?

4.2.5 Agroindustry and agricultural commerce

Technological demands are not always channeled toward public research institutes. For example, although the Swiss company Nestlé invests large financial resources in research, they have little contact with the public sector. Due to changes in legal status (the conversion of research institutes into independent foundations, as in the Netherlands and the UK), institutes have the freedom to contract and implement research for the private sector, and activity in this area has grown a great deal. Without legal provisions, the private sector may lack the confidence to work with the public sector. Public research is now paying more attention to topics related to agroindustry, for example, the theory of chain organization, food chemistry, mechanisms related to food toxicity, etc.

4.2.6 Collaborative research

The importance of collaborative research is increasing in the case study systems. To a large extent this represents a response to financial problems, but it also corresponds to scientific developments. Certain new research techniques have broad applicability: for example, a geographical information system is useful for agricultural research as well as for rural or transport planning. Similarly, molecular biology has many applications. The interest in collaboration has been caused by the need for greater efficiency as well by the financial pressure created when high-cost techniques are developed.

4.2.7 International and regional collaboration

There is clear interest in international collaboration. European-Community countries and Switzerland are oriented toward programs directed by the European Community in Brussels, and Australia is attempting to reduce its isolation. Within the USA, the international tendency is less clear but, in a country of that size, there is great potential for developing internal links. There is great value in sharing knowledge and this can be enhanced through collaboration.

Regional collaboration is more ad hoc and tend to be established according to personal contacts and interests. The European effort to establish a regional collaboration model (European Initiative for Agricultural Research for Development) was established only in 1995. At present, its main function is to generate databases on research projects of mutual interest in the European Community.

Private research tends to be focused on the global markets covered by the largest and most important companies. The position of private research in a particular country basically responds to two factors: (1) the companies' roots. For example, Unilever has large research programs in the countries where it originated (the UK and the Netherlands); and (2) the existence of a climate conducive to research (sufficient qualified personnel with extensive experience and the ability to protect research results through patents or breeders' rights). The establishment of private research within a country therefore depends to a great extent on the development of the scientific base.

4.2.8 Knowledge or technology?

In the case study systems, the degree of integration between institutes and universities is increasing and priority is being given to basic over applied research. Apart from economic reasons, an important factor seems to be the emphasis on knowledge over technology. Access to knowledge and the possibility to contribute to the knowledge base is higher in universities than in other research institutes, while knowledge can be diffused through students and graduates.

The emphasis on knowledge can be observed in many places. For example, the World Bank's annual report for 1998 indicates that a country's competitive position and economic quality are, for the most part, defined by the size and density of its "knowledge cloud." If there is a high degree of knowledge and this is widely dispersed, the agricultural sector (or any other) can be taken to a higher level and move further toward the technological frontier. At the same time, the density and size of the "knowledge cloud" influences the speed at which the technological potential of a country grows. Although no one can ever completely predict when and where it will rain, a dense cloud increases the probability of rain.

The technology system should recognize that the innovation process is very difficult to predict, but that the possibility for technological change is increased when there is a high knowledge level. By this means, research contributes to the knowledge cloud and, at the same time, is directed to specific problems as well as toward a country's environmental and competitive position. The emphasis on knowledge transfer through education and on the development of knowledge around central societal problems is essential to avoid the "Soviet disease." This refers to the fact that in the Soviet Union, research investment was very high, but there was no incentive for widespread technological change (except in the space industry).

Analysis of major changes in the agricultural research context shows that the research systems are confronting technological demands and conditions that are very different today, compared with 20 years ago. The demands on the research system have shifted from primary production toward the management of agroindustrial chains, and from productivity increases toward the improvement of food quality and safety. The generation of technologies for agricultural producers is ceasing to be

perceived as a public good. The challenge for research systems can be summarized as a change of identity: instead of 'technology factories,' they should become "knowledge sources."

4.3 Conclusions: Institutional innovations in response to the new context

4.3.1 Responses in areas of governance and management

Greater accountability. Within all of the case study systems, there have been efforts to increase the research systems' responsibility. However, the means to do this have been very different. Two major types of effort can be distinguished:

1. *Changes in procedures:* the Swiss emphasize "new public management" in institutes that continue to depend on the ministries and the British have introduced a program evaluation system that defines future financing.
2. *Structural changes:* the Dutch are "privatizing" their research institute and putting more emphasis on accountability. The Australians have, to a great extent, left the responsibility in the hands of the Research and Development Corporations that are managed by the sector.

Stakeholder participation. In Europe, efforts to give stakeholders greater decision-making power appear to have been consigned to the past. As the systems move toward developing public goods, it is not very clear whether decision-making power will be placed in the hands of producers or some other group. In either case, this type of governance would make a public focus difficult. In the Netherlands, the government is withdrawing from shared financing of adaptive research and is increasingly leaving responsibility and financing in the hands of producers. In Switzerland, the orientation of agricultural research is defined by public officials and scientists, and the tendency is to centralize this function. In the USA and Australia, there has been greater attention to stakeholder participation. In Australia, farmers have a certain degree of influence through matching funds but, at the same time, the government is looking at how to reduce its contributions to these funds. Throughout the case study countries, the principle appears to be "whoever wants to influence has to pay."

Flexibility in resource use. Attempts to increase the flexibility of scientific resource use have been introduced in several countries to encourage the system to respond better to new research demands and financial mechanisms. The most important means of doing this is through short-term contracts, for example, post-graduate PhD projects. Personnel administration plays a very important role in creating flexibility in the USA, the UK, Switzerland, and the Netherlands. The use of short-term contracts has interesting effects: on one hand, there is less job security and researchers are less able to investigate long-term problems or to become known as experts in their fields. On the other hand, the transfer of research professionals to other fields of research or employment helps diffuse and disseminate knowledge and allows institutions to select the best-qualified researchers for an individual project. In this way, some short-term contracts have favored system quality but, at the highest level, the approach can compromise system quality.

Speed and strength of change. Changes in the case study systems have been great over the past 15 years: for example, privatization in Holland and England, integration with universities in Switzerland, and changes in financing in Australia (matching funds) and in the USA (competitive funds). The effects on the morale of personnel within the systems have been different depending on the country. In England there is a certain degree of demoralization, whereas in Switzerland, the Netherlands, and the USA this is less evident. Two factors have had impact: (1) the great rapidity of the changes in England and the unclear direction of those changes; and (2) in England there was a dissatisfaction with the system's efficiency, whereas in the other countries the problems were more to do with the system's relevance. In England, there was less confidence between the government and the research system than in the other countries.

4.3.2 Financing

Separation of financing and implementation. In the USA, Australia, the Netherlands, and the UK there is greater separation between financing and implementation now than there was 15 years ago. In the USA, formula funds have become less important; in the Netherlands, the research system receives public funds according to the Ministry's priorities; in Australia, the RDCs make decisions on finance and CSIRO and others implement; and in England, the BBRSC defines the financing of the different institutions. More money is available through competitive funds (the USA and the UK). This separation is one of the best means to manage pluralist research systems, and it is for this reason that the smallest and least pluralist system (Switzerland) has not seen the need to separate these roles.

The search for competition. In the English-speaking countries, it is thought that the quality of public systems is improved when they function more as quasi-markets. In these countries, the emphasis on competitive funding has increased. High-quality portfolios have been developed using these funds, but the effects are not always positive. The functioning of competitive funds can be compared roughly to the extraction of cream after milking. The cream will keep, but if the remaining milk is not used, it deteriorates. So the question is: what happens to the scientific capacity that is not rewarded with funding? Competitive funds have high operational costs, and are best used to focus research on new topics or to induce a change in the orientation of research. In this case, those who are not awarded grants may be able to continue with funding levels that are lower but perhaps still sufficient to enable them to function satisfactorily.

The CRC scheme in Australia combines many of the attractive aspects of competitive grant funds and has none of their possible disadvantages. First, the scheme itself does not dominate resource allocation since it represents only a small proportion of total funds. Second, the funds are available for five years, which is relatively long term. Third, the CRCs have low operational costs. Finally, the CRCs focus on strategic topics of national importance. In Switzerland and the Netherlands, there has been no trend toward a greater use of competitive funds. One important consideration is that resources for research are insufficient to permit competition to be organized and also that these small countries are afraid of dispersing their scientific capacity.

Cofinancing models. Producer and government cofinancing has not increased in importance. This is especially the case in the USA, where the mechanism has never been prominent. In the UK, the establishment of a cofinancing mechanism met with little success after the European Union prohibited the previous mechanisms. In the Netherlands, the government has decided to finance its own interests and expects producers to do the same. In Australia, cofinancing was successfully established in the mid-1980s, but is now once again under discussion. Switzerland has no producer participation in the financing of public-sector research. Instead, producers decide for themselves where their interests lie.

Private research financing. This is concentrated within the input, machinery, equipment, and processing industries. In all case study countries except Australia, private entities spend more than public entities on research. They also tend to deal with different problems. It is not very clear whether the growth in private and public research is occurring in parallel. The growth in private research is defined, to a large extent, by the dynamics of the sector, and depends on the quality of management in the companies involved (for example, large firms dominate the private sector in Switzerland). The second factor is the legal framework and the degree of clarity that exists with respect to property rights. The third is the density of the knowledge cloud. Industry (above all, multinational industry) is interested in investing in research when it finds an environment conducive to the generation of results.

4.3.3 Research implementation

Integration of universities. In Switzerland, the Netherlands, the UK, and Australia, education and research are well integrated. In the USA, this integration has always been strong. Integration is partly a response to budgetary cuts, but it also reflects ideas about the importance of knowledge and the best means to diffuse results. In addition, combining scientific capacity with educational responsibilities permits greater flexibility and facilitates the development of a critical mass. Another positive element is the integration of agricultural with non-agricultural disciplines. However, political considerations also arise. For example, in the Netherlands, the LNV is consolidating and protecting its own system against competition from the Ministry of Education and Science.

Public-private research. In the UK, the Netherlands, the USA, and Australia, efforts are being made to establish mixed research mechanisms, programs or institutes. In general, interaction with the agroindustrial sector is greater than with the producers. The data tend to show limited overlap in activities. The (federal) mechanisms of collaboration with the private sector in the USA (CRADAs), in England (the LINK program), and the Netherlands (WFC) have small budgets in comparison with the budgets of each individual partner. To be successful, these initiatives should put greater emphasis on the process of knowledge sharing rather than the joint development of new technologies.

International collaboration. The importance of international collaboration is recognized in all of the case-study countries, and several initiatives have been established to develop this type of work. The Swiss established the Swiss Centre for International Agriculture; in Australia, joint ventures are sought with international firms; and in the UK and the Netherlands, the importance of European funds is growing. All four countries are participating in regional forums. However, the attitude within the countries seems to be rather passive, ad hoc, and self-centered. When possibilities become available they are used; if they improve the countries' individual positions they will be accepted; but few substantive initiatives are being taken to share programs or research facilities. A possible explanation could be that internal changes have consumed a lot of energy, and the internationalization of research might be a next step.

Research can give a comparative advantage to the agricultural sector within a country. If certain countries compete for the same markets, they are unlikely to want to share their resources. Consequently, regional collaboration should focus on topics that do not affective competitiveness, but that focus on countries' internal conditions (for example, natural or genetic resources), or on basic research and pre-competitive topics.

Legal frameworks. The legal frameworks for research have changed in several of the countries studied. The strengthening of patent legislation (for live organisms) in the USA and the change in the legal status of the Dutch DLO (converting the organization into a private foundation) are events that have great impact on research implementation. Increasingly, legal management seems to be one of the conditions that are essential for achieving an effective research system.

4.3.4 The nature of change in the case study systems

The changes occurring in the countries studied have been very significant. Some of the innovations introduced involve changes in legal status, introduction of competition, integration of universities, strengthening of legal frameworks, and establishing new methods of collaboration. The majority of these innovations have originated in existing institutions. According to figure 1.3, the perception is that, in the past, the research systems were generally more efficient than relevant. Modifications aimed at increasing efficiency have been introduced, but have received less attention than institutional innovations. Efforts to increase relevancy have been least disruptive in the USA, since the research structure can satisfy many of the new requirements. In the UK, both the efficiency and the relevancy of the research system were in question, and institutes were closed down and financing

was strongly redirected toward universities. Nevertheless, in nearly all cases, the preferred change strategy has been to transform the existing "technology factories" into "knowledge sources."

4.4 Implications for developing countries

It would be ill-considered to define direct implications for the developing world as a result of the tendencies analyzed in five developed countries. First, not all developing countries face the same degree of contextual change as the countries under study. Second, each country and research system has unique characteristics. All systems have a specific history and are in different stages of development. The individual history and characteristics largely define the viability and adequacy of a system's response to external changes. Similarly, changes tend to provoke a mixture of responses. The mixture again depends on the specific circumstances of the agricultural research system of a particular country. Nevertheless, many countries in the developing world face similar changes to those described in the five case study countries and, therefore, the responses of the reviewed countries may offer valuable and useful suggestions. At least, this analysis will raise awareness for necessary innovations, extend the set of options and potential responses, and provide certain analytical lessons that could be useful for decision making in countries that are reviewing their agricultural research systems.

The main points resulting from the analysis are as follows:

1. It is worth asking whether the priority for a given research system should be to respond to changes in the external environment or merely to improve its efficiency in delivering current outputs. At present, changes are occurring very rapidly due to globalization, concern for the environment and sustainable use of natural resources, review of the public sector, and new research methodologies. The developed-country systems have especially been concerned with adapting to contextual changes, and are attempting to define their relevancy in a society that presents new technological demands, new scientific opportunities, and new forms of public organization. Improving a system's efficiency without taking into consideration its relevance is a risky strategy, possibly even a pointless one.
2. The evidence found in the UK, the Netherlands, and Switzerland shows that, over the years, the positions of the agricultural sector and research have changed. In the public sector, political positions (and the influence of agriculture) change in response to development processes. The result is that the agricultural research system will increasingly be subjected to requests from outside the sector. The emphasis is shifting away from the development of productivity increasing technologies towards that of new approaches to social and environmental issues, such as the protection of natural resources, food safety, and animal welfare. The challenge is to promote development that balances equity and environmental interests with those of economic growth, while limiting the negative external effects of agriculture. The need for more sustainable use of water resources is one example for future research efforts that is rapidly gaining importance in many developing countries.
3. In the future, public research systems will be increasingly oriented toward the generation of knowledge, while the private sector assumes a greater role in technology generation. The growing emphasis on knowledge creation reinforces the importance of integrating universities within the research system, as has been observed in the case of Switzerland, the Netherlands, the UK, and Australia. Sharing creates opportunities for interested parties to apply knowledge in new technologies or procedures and enhances the diffusion of research results. Sharing knowledge will create new opportunities for transferring technologies or methods and for enhancing the dissemination of research results. It will also promote the development of a more sophisticated agricultural sector, with links to other sectors and disciplines.
4. In some countries, financial pressures on the research system have resulted in a healthier system in which new modes of operation have come into being and relevance has been considerably improved. The USA, Australia and the UK in particular have seen increased emphasis on the use of competitive grants, which has led to the development of high-quality research port-

folios. However, such funding mechanisms have high operational costs. Moreover, small research systems may not allow sufficient scope for real competition. Research managers should therefore analyze the pros and cons of competitive grants and other new funding mechanisms carefully before introducing them into their own systems.

5. In all the countries under study, the conduct of research by the public sector has been the subject of review. Since the public-good argument is the rationale for the existence of public sector research systems, it is of utmost importance to define the roles of the public and the private sector clearly. These roles vary from country to country as a function of (1) the failure of markets to produce the amount and kind of research that are in the best interests of society; (2) the need to enhance or maintain the competitive structure of markets; and (3) the existence of opportunities for exploiting the complementarity of research and education. The definition and clear assignment of responsibilities in the public and the private sectors is not an easy task because it leaves room for interpretation and also changes over time.
6. A major trend observed in the case study countries is that agricultural research systems are opening up to include new, nontraditional players. Stronger collaboration is being sought with the private sector and with NGOs. The latter are playing an increasingly demonstrative part in articulating the demand for new technologies and knowledge of relevance to the poorer segments of society. Furthermore, the importance of international and regional partnerships has been recognized. At the same time, the boundaries of agricultural research systems are becoming blurred as more network-type arrangements between institutions in different sectors are taking shape. This trend is providing all who participate with access to a wider circle of experience than can be found in the agricultural sector alone and is increasing the relevance of research outputs to a broader set of stakeholders.
7. The combination of declining political support and reduced core funding, together with the drive to make the research system more responsive to changing social needs, has resulted in a trend—most advanced in the Netherlands—toward the separation of research decision-making and funding from the execution of research. Separating the two functions is seen as one of the best ways of managing a complex and pluralistic research system; it reflects efforts to enhance accountability and to respond better to the demands of an increasingly diverse group of stakeholders.

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