*The Australian Journal of Agricultural and Resource Economics*, 42:1, pp. 51–82

# Financing agricultural R&D in rich countries: what's happening and why

Julian M. Alston, Philip G. Pardey, and Vincent H. Smith*

Governments everywhere are trimming their support for agricultural R&D, giving greater scrutiny to the support that they do provide, and reforming the public agencies that fund, oversee, and carry out the research. This represents a break from previous patterns, which had consisted of expansion in the public funds for agricultural R&D. Private-sector spending on agricultural research has slowed along with the growth of public spending in recent years, but the balance continues to shift towards the private sector. This article presents a quantitative review of these funding trends and the considerable institutional changes that have accompanied them. We discuss new data for 22 OECD countries, providing institutional details for five of these countries, and conclude with an assessment of policy developments.

## 1. Introduction

Public agricultural research institutions and the policies that surround them are at a pivotal point in their history. In many countries, in both the developed and the developing world, public agricultural R&D policy has changed dramatically since the early 1980s. A long period of sustained growth appears to have ended, and many believe that we have entered a phase of general fiscal restraint, which, combined, with a more sceptical view of the social benefits from investments in science, have led to a tightening of resources available for research and calls for clearer justification for R&D funds and accountability for their use.

* Julian Alston is a Professor in the Department of Agricultural and Resource Economics at the University of California, Davis and a member of the Giannini Foundation of Agricultural Economics, Philip Pardey is a Research Fellow at the International Food Policy Research Institute, Washington, DC, and Vincent Smith is an Associate Professor in the Department of Agricultural Economics, Montana State University. Authors are listed alphabetically, senior authorship is unassigned. John Mullen provided helpful comments on an earlier version, for which we are grateful. Partial support for this work was provided by the UK Department for International Development and the University of California Pacific Rim project.

This article documents the nature and scope of these changes in five developed countries: Australia, the Netherlands, New Zealand, the United Kingdom, and the United States.[1] These countries are of particular interest because they have long histories of active public agricultural R&D policies and, taken together, they account for over 40 per cent of total public agricultural R&D by OECD countries. In addition, they include some of the most innovative countries with respect to changes in agricultural R&D policies; lessons learned there could be useful elsewhere.

Agricultural R&D policies have often been described purely in terms of total public funding, which may be appropriate when the institutions that manage and carry out publicly funded agricultural research remain relatively stable. However, when an explicit goal of public agricultural R&D policy is to alter the structure and function of those institutions, as has been the case in all but one of the countries examined here (the exception being the United States), trends in public funding tell only a part of the story, albeit an important part. Here we consider agricultural R&D policy developments over the past twenty years in a broader sense for each of the five countries of interest, examining not only public funding trends for agricultural research, but also changes in agricultural R&D institutions.

Many aspects of the recent agricultural R&D policy changes have been remarkably similar among the countries, but there have been some important differences with respect to both the timing and the substance of policy innovations. The similarities derive from a set of common 'vectors for change' that have come into play in each of the countries, including the advent of political administrations with more market-oriented, *laissez-faire* views of the role of government in the management of the national economy, the changing nature of scientific research, the development of a more sceptical view of the potential benefits from agricultural R&D, and the growing influence of 'non-traditional' interest groups (such as agribusiness, food industry, environmental, and food safety lobbies) on the public agricultural R&D agenda.

[1] A forthcoming volume, edited by Alston, Pardey, and Smith (1997) documents recent changes in agricultural research institutions and investments in Australia, the Netherlands, New Zealand, the United Kingdom, and the United States in detail. The chapters on individual countries were written by Alston, Harris, Mullen, and Pardey (1997)—Australia; Alston, Christian and Pardey (1997)—the United States; Jacobsen and Scobie (1997)—New Zealand; Thirtle, Piesse, and Smith (1997)—the United Kingdom; Roseboom and Rutten (1997)—the Netherlands. A chapter in that volume by Pardey, Roseboom, and Craig (1997) provides an overview for the OECD as a whole. The current article draws heavily on those items.

Many of the recent agricultural science policy changes have been intended, at least ostensibly, to shift the burden for the funding and execution of some types of agricultural research from the public sector to the private sector. In most countries, aside from its own research investments, the private sector has had a long-standing active interest in public agricultural R&D. As primary users of the outputs of public R&D systems, agricultural producers, food processors, and other agribusiness firms have been involved in the management of publicly provided R&D funds. In addition, through various mechanisms, private firms have funded publicly performed agricultural R&D, or performed publicly funded agricultural research. This article pays particular attention to the degree to which each of these three roles of the private sector has become more or less important, and the extent to which changes in those roles have been linked to changes in public agricultural R&D policies.

## 2. Public investment in national agricultural research[2]

In most countries, public-sector involvement in agricultural R&D has been important for less than 100 years. Its evolution has not been smooth.

### 2.1 Genesis and historical development of public agricultural research

In many countries, formalised agricultural research institutions supported by national governments were first instituted between the middle and the end of the nineteenth century. Research developments in these countries occurred in waves, with common undercurrents in different countries. The first wave of development involved the initial establishment in the middle of the nineteenth century of various agricultural experiment stations in France, Germany and the United Kingdom, partly in response to the emergence of the formal agricultural sciences through the work and writings of

[2] There is no single, internationally accepted notion of what constitutes 'agricultural R&D'. Like Pardey, Roseboom and Craig (1997)—from which much of the data reported here are drawn—this article uses a broad notion of agricultural research, and follows the science and technology measurement standards laid down by OECD (1994). Research related to 'agriculture' is taken to include crops, livestock, forestry, and fisheries research and related environmental R&D. It includes research targeted to the development of pre-production (e.g., input supply), on-farm, and post-production (e.g., food processing) technologies. These data are reported primarily on a 'performer' basis, but we distinguish between the public and private performance versus funding of R&D where that is possible and it makes policy sense to do so. Our series for Australia do not compare directly with the data reported by Mullen, Lee and Wrigley (1996). Their series explicitly excludes processing R&D and is targeted to production agricultural R&D excluding forestry and fisheries research.

Boussingault, von Liebig, and Lawes at that time. The practice of providing public funds to support national agricultural research agencies staffed with professional scientists (introduced for the first time in Mockern, Saxony in 1852) spread rapidly throughout Europe. By 1875 over 90 European agricultural experiment stations had been established and the process of expansion continued throughout the rest of the century (Grantham 1984). In the Netherlands, for example, the first publicly funded agricultural experiment station was created at Wageningen in 1877, and additional public agricultural research, monitoring, and testing facilities were rapidly established between 1880 and 1900. Similar developments took place in Australia (where the Victorian Board of Agriculture took over the first experimental farm in the 1850s—see Baker, Baklien, and Watson 1990; and McLean 1982) and the United States (where the first agricultural experiment station was established at Yale in 1875—see Kerr 1987), as well as other countries (e.g., Japan—see Hayami and Yamada 1975; and True and Crosby 1902).

By the turn of the century, the scientific foundations of agricultural R&D had become more fully developed. Darwin's theory of evolution, the pure-line theory of Johannson, the mutation theory of de Vries, and the rediscovery of Mendel's Laws all contributed to the rise of plant breeding. Pasteur's germ theory of disease and the development of vaccines opened up lines of research in the veterinary sciences. These developments provided the scientific basis for a second steady wave of expansion in public commitment to agricultural R&D during the first half of the twentieth century.[3]

The evolution of the science of genetics gathered pace around the middle of this century as Hersey and Chase, Watson and Crick, and others uncovered the role and structure of DNA that led directly to the modern biotechnologies based on recombinant DNA techniques, monoclonal antibodies, and new cell and tissue culture technologies. These changes in the practice of biological science paralleled efforts by governments to enact legislation strengthening intellectual property protection applied to living organisms, such as new plant varieties and related genetic material, and to implement a range of public science policies that stretched well beyond agriculture. Together these developments fundamentally changed the nature of the agricultural sciences, with implications for public and private roles in agricultural research, and the balance between locally provided and

[3] These are only a few examples of the innovations in the biological and other basic sciences that underpinned progress in the agriculture sciences and technical change in agriculture during the earlier part of this century. See Salmon and Hanson (1964) for the details of these discoveries.

internationally traded R&D goods and services.[4] It was fortuitous, perhaps, that many of the discoveries on which modern agricultural science methods are based were made shortly after the end of World War II, a period when science and technology were perceived widely as a potential source of large improvements in social welfare. The result was a massive third wave of public investment in science and technology research in general and agricultural research in particular.

In real terms, between 1945 and the mid-1970s, in most developed countries public expenditures on agricultural R&D grew more rapidly than in the rest of the post-WW II period.[5] Then in the mid-1970s, rates of growth in public R&D outlays slowed quite markedly and, in the 1980s, public agricultural R&D expenditures generally stagnated or declined. In the 1990s, however, public agricultural R&D expenditures recovered or began to increase again, but at much more modest rates of growth than in the 1960s and early 1970s. Changes in research focus and other elements of R&D policy were associated with these recent funding shifts, and accelerating changes in telecommunications (especially the development of the Internet) have unleashed a new wave of significant institutional and other changes in the agricultural sciences.

## 2.2 Trends in public agricultural R&D funding in OECD countries

Data on public agricultural R&D expenditures, measured in real, 1985 international dollars,[6] and their rates of growth over the period 1971 to 1993 are presented in table 1 for 22 member countries of the Organization for

[4] For example, the United States has had plant patents for asexually reproduced cultivars since the 1930s, Plant Variety Protection Certificates since the 1970s, and utility patents for living organisms have been available since the landmark *ex parte Hibberd* decision of 1985. The agreement on Trade Related Intellectual Property Protection (TRIPS) (specifically, annex 1c of the 1995 Marrakesh Agreement establishing the World Trade Organization) mandates the extension of intellectual property protection to plants.

[5] For example, between 1950 and 1970, in real terms public agricultural R&D expenditures increased at annual average growth rates of about 7 per cent in Australia (Alston, Pardey and Smith 1997), about 7.4 per cent in the United Kingdom (Thirtle, Piesse and Smith 1997), and about 2.8 per cent in the United States (Alston, Christian and Pardey 1997). Although similar data are not available for the Netherlands and New Zealand for this period, Roseboom and Rutten (1997) and Jacobsen and Scobie (1997) report that those countries also substantially increased public investments in agricultural R&D between 1950 and 1970.

[6] All the expenditure data in this article are reported in 1985 international dollars. Expenditures were compiled in current local currency units, deflated to 1985 prices using local implicit GDP deflators obtained from the World Bank's (1995) *World Tables,* and then converted to international dollars using purchasing power parity rates for 1985 obtained from Heston, Summers, Nuxoll and Aten (1995).

**Table 1** Real public agricultural R&D spending in OECD countries, 1971–93

| | (millions of 1985 international dollars)[b] | | | | Annual growth rates (%) | | |
|---|---|---|---|---|---|---|---|
| | 1971 | 1981 | 1991 | 1993 | 1971–81 | 1981–93 | 1971–93 |
| Australia | 238.7 | 281.9 | 307.8 | 315.4 | 2.1 | 0.3 | 1.2 |
| Netherlands | 134.7 | 202.1 | 216.6 | 229.7 | 4.2 | 0.9 | 1.6 |
| New Zealand | 114.3 | 133.8 | 110.2 | 107.3 | 2.2 | −2.2 | 0.2 |
| United Kingdom | 274.5 | 371.0 | 364.4 | 370.8 | 2.6 | −0.2 | 1.2 |
| United States | 1 235.6 | 1 620.4 | 2 023.4 | 2 054.3 | 2.4 | 2.3 | 2.1 |
| *Sub-total (5)*[a] | *1 997.8* | *2 609.1* | *3 022.4* | *3 074.5* | *2.5* | *1.4* | *1.8* |
| Other OECD (17)[a] | 2 300.2 | 3 104.3 | 3 919.1 | 4 054.9 | 2.9 | 2.1 | 2.6 |
| *Total OECD (22)*[a] | *4 298.1* | *5 713.4* | *6 941.4* | *7 129.4* | *2.7* | *1.8* | *2.2* |

Notes: [a] Figures in parentheses indicate the number of countries included in the respective totals.
[b] Research expenditures denominated in current local currency units are first deflated to 1985 prices using local implicit GDP deflators taken from World Bank (1995) and then converted to international dollars (where one international dollar is set equal to one US dollar) using the purchasing power parities taken from Heston, Summers, Nuxoll and Aten (1995).

Source: Pardey, Roseboom and Craig (1997).

Economic Cooperation and Development (OECD) and for each of the five OECD countries of particular interest here: Australia, the Netherlands, New Zealand, the United Kingdom, and the United States.[7] The 22 member countries of the OECD together account for over 90 per cent of all developed-country agricultural R&D, and, therefore, trends in agricultural R&D spending in these countries provide useful contexts for evaluating trends in agricultural R&D spending in the five countries of interest. It is also useful to compare trends in those five countries, which accounted for over 40 per cent of public agricultural R&D outlays by OECD countries during this period, with trends in the other seventeen OECD countries

Between 1971 and 1993, as the data in table 1 indicate, spending on agricultural R&D by the 22 OECD member countries increased from about US$4.3 billion to about US$7.1 billion at an annual average growth rate of about 2.2 per cent. However, this 22-year period can be divided into two distinct periods, 1971–81 and 1981–93. In the first period, essentially the decade of the 1970s, total public OECD agricultural R&D expenditures increased at an annual average growth rate of 2.7 per cent; in the 1980s and early 1990s, the annual average growth rate fell by about one third, to 1.8 per cent.

[7] The 22 member countries of the OECD included in many of the 'OECD totals' reported here are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

The five countries of particular interest had markedly slower average annual growth rates in public agricultural R&D expenditures than the OECD as a whole, but the general pattern of growth in the five countries was similar to overall growth among the OECD countries. The differences and similarities between the five selected countries and the other OECD countries are even more apparent when growth rates in public agricultural R&D expenditures for those other seventeen countries are examined. Over the period 1971–93, total public agricultural R&D outlays in the seventeen countries increased by over 75 per cent. In the first sub-period, 1971–81, the annual average growth rate in public agricultural R&D for these seventeen countries was 2.9 per cent; in the second period, 1981–93, it fell by more than one quarter to 2.1 per cent. However, between these two periods, the growth rate of public agricultural R&D expenditures fell by two-fifths in the five selected countries.

Among themselves, the five countries exhibited some important differences with respect to funding trends. In the United States, real public agricultural R&D expenditures, measured in 1985 prices, increased from about US$1.2 billion in 1971 to just under US$2.1 billion in 1993, an annual average growth rate of 2.3 per cent—compared with 2.2 per cent for all OECD countries, and 2.6 per cent for the other seventeen OECD countries over the same period. Moreover, the shift in the annual growth rate of public agricultural R&D expenditures in the United States, from 2.7 per cent in the 1970s to 2.1 per cent in the 1980s, was also closely paralleled in the other seventeen OECD countries. In contrast, between 1971 and 1993, public agricultural R&D expenditures in Australia, the United Kingdom, and the Netherlands increased at much lower annual average growth rates of between 1.2 per cent and 1.6 per cent, and public agricultural R&D expenditures in New Zealand barely increased at all. These low average annual growth rates for the entire period were the result of precipitous declines in annual average growth rates in public agricultural research in Australia and the Netherlands, and absolute declines (i.e., negative growth) in New Zealand and the United Kingdom over the period 1981–93.

Among the other seventeen OECD countries, only three countries—Belgium, Canada and Greece—also experienced reductions in real public agricultural R&D spending over the period 1981–93. Thus, four of the five countries examined in this study experienced more dramatic changes in public agricultural R&D funding trends than most other OECD countries. During the 1980s, governments in these four countries (Australia, the Netherlands, New Zealand, and the United Kingdom) also implemented more radical changes with respect to the institutional organisation and management of public agricultural research than the US government did.

**Table 2** University share of public agricultural R&D spending, 1971–93 (in percentages)

| | 1971 | 1981 | 1991 | 1993 |
|---|---|---|---|---|
| Australia | 10.7 | 8.2 | 11.5 | 11.6 |
| Netherlands | 14.9 | 22.1 | 31.8 | 31.9 |
| New Zealand | 13.0 | 13.0 | 17.8 | 13.6 |
| United Kingdom | 2.3 | 2.9 | 9.7 | 14.7 |
| United States[a] | 67.3 | 67.5 | 74.0 | 74.1 |
| *Sub-total (5)*[b] | *45.0* | *45.6* | *54.8* | *55.3* |
| Other OECD (14)[b] | 27.5 | 25.6 | 28.2 | 28.0 |
| *Total OECD (19)*[b] | *38.8* | *37.9* | *43.0* | *43.2* |

Notes: [a] University research in the United States includes research undertaken by the State Agricultural Experiment Stations operated in conjunction with the state land-grant universities.
[b] Figures in parentheses indicate the number of countries included in the respective totals.
Source: Pardey, Roseboom and Craig (1997).

Data on the share of public funds provided to support research at universities are presented in table 2 for each of the five countries and fourteen other OECD countries for which such data were available. In all of the five countries, between 1971 and 1993, the university share of total public agricultural R&D spending increased.[8] In Australia and New Zealand, the increases were very modest (university share rose from 10.7 per cent to 11.6 per cent and from 13.0 per cent to 13.6 per cent, respectively), but in the other three countries, the increases were substantial. In the United Kingdom, the university share increased from 2.3 per cent to 14.7 per cent, in the Netherlands it increased from 14.9 per cent to 31.9 per cent, and in the United States it increased from 67.3 per cent to 74.1 per cent. In the other fourteen OECD countries, the average share of public agricultural R&D funds channelled to universities changed little, from 27.5 per cent to 28.0 per cent over the same period. Thus there is some evidence that the five countries are somewhat atypical with respect to the reallocation of research funds towards universities.

The annual rates of growth in public agricultural R&D expenditures in both the five countries and the other seventeen OECD countries were quite small in the 1970s, compared with the annual growth rates of 7 to 8 per cent experienced during the 1950s and 1960s in Australia, the United Kingdom, the United States, and many other countries. During the 1950s and 1960s, many developed countries financed large-scale expansions in their national science research-education systems. Agricultural science did well, possibly

[8] This parallels broader trends towards an increased share for universities in total public spending on all science research (*The Economist* 1997).

**Table 3** Real public agricultural R&D spending in developed and developing countries, 1971–91

| | (millions of 1985 international dollars) | | |
|---|---|---|---|
| | 1971 | 1981 | 1991 |
| *Expenditures* | | | |
| Developing countries (131)[a] | 2 984 | 5 503 | 8 009 |
| Sub-Saharan Africa (44)[a] | 699 | 927 | 968 |
| China | 457 | 939 | 1 494 |
| Asia and Pacific, excl. China (28)[a] | 861 | 1 922 | 3 502 |
| Latin America and Caribbean (38)[a] | 507 | 981 | 944 |
| West Asia and North Africa (20)[a] | 459 | 733 | 1 100 |
| Developed countries (22)[a] | 4 298 | 5 713 | 6 941 |
| *Total (153)*[a] | *7 282* | *11 217*[b] | *14 951*[b] |
| | (percentages) | | |
| | 1971–81 | 1981–91 | 1971–91 |
| *Average annual growth rates* | | | |
| Developing countries | 6.4 | 3.9 | 5.1 |
| Sub-Saharan Africa | 2.5 | 0.8 | 1.6 |
| China | 7.7 | 4.7 | 6.3 |
| Asia and Pacific (excl. China) | 8.7 | 6.2 | 7.3 |
| Latin America and Caribbean | 7.0 | – 0.5 | 2.7 |
| West Asia and North Africa | 4.3 | 4.1 | 4.8 |
| Developed countries | 2.7 | 1.7 | 2.3 |
| *Total* | *4.3* | *2.9* | *3.6* |

Note: Regional groupings of countries are given in the appendix table in Pardey, Roseboom and Anderson (1991); the sub-Saharan Africa group reported here includes South Africa. The data from the series published in 1991 form the basis of the revised and updated ASTI data reported in the current table.

[a] Figures in parentheses indicate the number of countries included in the respective totals.

[b] Each cell entry was rounded, therefore the reported sum of the columns may not equal the sum of the reported columns.

Sources: Pardey, Roseboom and Craig (1997) for developed countries. The IFPRI-ISNAR Agricultural Science and Technology Indicators (ASTI) database for developing countries.

because the agricultural sector was politically effective, but also because shortages during and immediately after World War II stimulated a demand for investment in R&D to assure security of future food and fibre supplies.

## 2.3 Global perspectives on public agricultural R&D expenditure trends

The pattern of decline in growth rates of public agricultural R&D expenditures in the 1980s was not restricted to developed economies. Nor was it entirely restricted to agricultural R&D. Some perspective is provided by considering global agricultural R&D funding patterns and funding trends for general science and technology R&D. Estimates of global public agricultural R&D expenditures, disaggregated by developing countries and developed countries, are presented in table 3.

*Developing country trends*

Between 1971 and 1991, public expenditures on agricultural R&D in developing countries increased from just under US$3 billion to just over US$8 billion, at an annual average growth rate of 5.1 per cent. These expenditures grew most rapidly over the entire period in China (6.3 per cent per year), other East Asia and Pacific Rim countries (7.3 per cent per year) and West Asia and North Africa (4.3 per cent per year). These are countries that, for the most part, have also enjoyed relatively rapid economic growth rates. Public agricultural R&D expenditures grew much more slowly in sub-Saharan Africa (1.6 per cent per year) and Latin America and the Caribbean (2.7 per cent), regions that include many countries with very low per capita incomes and low rates of economic growth. However, as in the developed countries of the OECD, public agricultural R&D funding trends in developing countries changed clearly and markedly in the 1980s. Between 1971 and 1981, public agricultural R&D expenditures in developing countries grew at an annual rate of 6.4 per cent, but between 1981 and 1991 they grew at an annual rate of only 3.9 per cent.

The data on public agricultural R&D expenditures by developing countries presented in table 3 are consistent with two conjectures. First, on average, between 1971 and 1991, growth rates of public agricultural R&D expenditures in developing countries were more than twice those experienced in developed countries. Even higher growth rates in R&D expenditure were achieved in developing countries enjoying faster economic growth, and these more rapidly developing countries appear to have been building modern national agricultural research systems in the 1970s and 1980s, just as more developed countries did in the 1950s and 1960s and prior to World War II. Second, it seems likely that at least some of the factors that led to reductions in growth rates of public agricultural R&D expenditures in the OECD countries were also at work in the developing countries.

*International research*

Internationally conceived and funded agricultural research complements the work of national research agencies. This international R&D represents a relatively recent institutional innovation. The first such venture, a cooperative Mexican government–Rockefeller program initiated in 1943 to conduct wheat research, became the model for many of the subsequent programs in international agricultural research, and later evolved into the International Wheat and Maize Research Center (CIMMYT). The further development of international agricultural research centres took place largely under the auspices of the Consultative Group on International Agricultural Research (CGIAR), which was established in 1971.[9] Funds for the CGIAR system are mainly obtained from the foreign aid (not agricultural R&D) budgets of developed countries, and are given directly to CGIAR centres or through contributions to agencies such as the World Bank, the Asian Development Bank, and the European Union.[10] The chronology of funding for the CGIAR system since 1972 involves two distinct phases. In the first phase, lasting from 1971 to 1982, real spending grew by 14.3 per cent per year as the CGIAR system expanded to include more centres and to cover more commodities. In the second phase, beginning in the mid-1980s, while the research mandate for the CGIAR continued to broaden to include additional commodities and a greater emphasis on environmental R&D, real spending began to stagnate, increasing by only 1.4 per cent per year between 1985 and 1991 and by only 0.5 per cent per year from 1991 to 1996. Thus, funding for international agricultural research, largely provided by the OECD countries, has followed a quite similar pattern to public agricultural R&D funding in those countries.

## 2.4 Public funding for all R&D for science and technology

Developments in public agricultural R&D funding are intertwined with developments in public funding for R&D into science and technology more generally. Data on overall public funding for all science and technology research in OECD countries are presented in table 4 for the period 1981–93. In addition, table 4 also includes research intensity ratios showing the value of publicly performed R&D for all science and technology relative to gross domestic product for all 22 OECD countries and each of the five countries over the same period.

---

[9] In 1996, the CGIAR spent US$326 million, less than 2 per cent of the public investment in agricultural R&D worldwide. For more details on institutional developments related to the CGIAR see Baum (1986), Gryseels and Anderson (1991), and Pardey *et al*. (1997). Gryseels and Anderson (1991) identify a further seventeen multilateral agricultural research agencies that were operating outside the CGIAR system in the mid-1980s. In addition, L'Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM) and Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) are two French-funded institutions that undertake research of direct relevance to (sub-)tropical agriculture in developing countries. In 1992 these two agencies collectively spent US$368 million on R&D.

[10] In 1995 the CGIAR received 31 per cent of its funding from the European Union, just over 12 per cent each from Japan and the United States, and 15 per cent from the World Bank (Pardey *et al*. 1997).

**Table 4** Real, total (agriculture and non-agriculture) public R&D spending in OECD countries, 1981–93

| | (percentages) | | | |
|---|---|---|---|---|
| | 1981 | 1991 | 1992 | 1993 |
| *Total publicly performed R&D relative to total output* | | | | |
| Australia | 0.84 | 1.00[a] | 0.98 | 0.91 |
| The Netherlands | 0.95 | 0.99 | 0.99 | 0.99 |
| New Zealand | 0.86 | 0.71 | 0.83 | 0.82 |
| United Kingdom | 1.07 | 0.86 | 0.87 | 0.86 |
| United States | 0.78 | 0.84 | 0.84 | 0.83 |
| *Subtotal (5)*[b] | *0.82* | *0.85* | *0.85* | *0.84* |
| Other OECD (17)[b] | 0.74 | 0.84 | 0.86 | 0.89 |
| *Total OECD (22)*[b] | *0.78* | *0.85* | *0.86* | *0.87* |
| | (billions of 1985 international dollars) | | | |
| *Public funding for all R&D* | | | | |
| Total OECD (22)[b] | 91.6 | 120.8 | na | 120.0 |

Notes: [a] 1990 figure.
[b] Figures in parentheses indicate the number of countries included in the respective totals.
Source: Pardey, Roseboom and Craig (1997).

Between 1981 and 1993, in aggregate in the 22 OECD countries, public funding for all science and technology R&D increased from US$91.6 billion to US$120.0 billion at an annual average growth rate of 2.4 per cent. Over the same period, as noted above, public funding for agricultural R&D by OECD countries increased by about 1.8 per cent per year. The average science and technology research intensity ratio (measuring total public R&D relative to GDP) for all 22 OECD countries was 0.78 per cent in 1981 and 0.87 per cent in 1993, increasing by a much smaller proportion than the agricultural research intensities (measuring public agricultural R&D spending relative to agricultural GDP) for twenty OECD countries, which rose from 1.83 per cent in 1981 to 2.48 per cent in 1992.

According to these research intensity measures, agriculture has been treated relatively favourably in most developed countries with respect to the provision of public R&D funds in the recent past. However, this comparison is confounded by the role of overall growth in the different sectors, the denominator of the research intensity ratio. A different picture emerges when trends in agriculture's share of total publicly performed science and technology are examined. These data are presented in table 5 for OECD countries over the period 1981 to 1993. In the 22 OECD countries, on average, agriculture's share of the total public science and technology R&D

**Table 5** Agriculture's share of public R&D spending in OECD countries, 1981–93 (percentages)

| | 1981 | 1986 | 1991 | 1993 |
|---|---|---|---|---|
| Australia | 19.9 | 18.0 | 14.1 | 14.8 |
| Netherlands | 14.5 | 12.4 | 12.0 | 12.4 |
| New Zealand | 49.1 | 49.5 | 46.7 | 35.5 |
| United Kingdom | 7.1 | 7.2 | 6.6 | 6.6 |
| United States | 6.2 | 5.5 | 5.7 | 5.6 |
| *Subtotal (5)*[a] | *7.6* | *6.7* | *6.7* | *6.6* |
| Other OECD (17)[a] | 10.3 | 9.6 | 8.5 | 8.3 |
| *Total OECD (22)*[a] | *8.9* | *8.1* | *7.6* | *7.4* |

Note: [a] Figures in parentheses indicate the number of countries included in the respective totals.
Source: Pardey, Roseboom and Craig (1997).

budget declined from 8.9 per cent in 1981 to 7.4 per cent in 1993, a proportional decrease of almost 17 per cent. In the five countries, on average, the change in agriculture's share of the total public science and technology research budget was quite similar, falling from 7.6 per cent to 6.6 per cent but, again, these average data disguise considerable differences between individual countries. In the United Kingdom and the United States, agriculture's share of the total public R&D budget declined quite modestly between 1981 and 1993 (from 7.1 per cent to 6.6 per cent in the United Kingdom and from 6.2 per cent to 5.6 per cent in the United States). In contrast, in the other countries, agriculture's share of the total public R&D budget declined quite dramatically (from 19.9 per cent to 14.8 per cent in Australia, from 49.1 per cent to 35.5 per cent in New Zealand, and from 14.5 per cent in 1981 to 12.4 per cent in the Netherlands.

In the three countries in which agriculture had the largest shares of total R&D budgets in 1981—Australia, the Netherlands, and New Zealand—the importance of agricultural research declined most substantially. Pressures to reallocate funds to other science R&D programs such as health were, perhaps, more severe in those cases. In fact, in all but one of the five countries (the Netherlands), between 1981 and 1993 the share of total public science R&D budgets allocated to health research increased quite substantially, at the expense of both agricultural research and defence research.

## 2.5 Private–public links between science and technology R&D funding and performance

Funding for agricultural R&D is increasingly intertwined with funding for research more generally. Measuring R&D investments becomes more challenging as the institutions involved in funding, managing, and

**Table 6** Total R&D by performer and source of funds

| | (billions of 1985 international dollars) | | | | Annual growth (%) |
|---|---|---|---|---|---|
| | 1981 | 1986 | 1991 | 1993 | 1981–93 |
| *R&D performers* | | | | | |
| Private | 120.6 | 167.7 | 199.2 | 190.8 | 4.3 |
| Public | 64.4 | 78.1 | 91.3 | 95.8 | 3.5 |
| Total | 185.1 | 245.8 | 290.5 | 286.6 | 4.0 |
| *Source of funds* | | | | | |
| Private | 93.6 | 131.6 | 169.7 | 166.6 | 5.4 |
| Public | 91.6 | 114.3 | 120.8 | 120.0 | 2.4 |
| Total | 185.1 | 245.8 | 290.5 | 286.6 | 4.0 |
| *Imputed net flow of funds from public to private performers* | | | | | |
| | 27.0 | 36.2 | 29.5 | 24.2 | na |
| *Net flow of public funds to private performers as a share of private R&D (percentages)* | | | | | |
| | 22.4 | 21.6 | 14.8 | 12.7 | na |

Note: Derived from Gross Expenditure on R&D (GERD) data included in table 1 of OECD (1996). Data include 22 OECD countries.
Source: Pardey, Roseboom and Craig (1997).

performing research evolve and become more complex. Distinguishing between those who fund R&D (and, perhaps, who manage the funds) and those who perform the research provides a clearer picture of changing institutional roles within programs of national research. It also facilitates international comparisons and enables useful policy insights to be drawn from the data. The data reported in table 6 on total science and technology R&D expenditures by OECD countries are separated into public and private categories on the basis of both research performers and research funders. Care has been taken to maintain a consistent institutional coverage over time, and to make the data comparable across countries. Although some unavoidable discrepancies remain, these data provide a reasonable basis for making broad international comparisons.[11]

Overall, public and private investment in all forms of R&D (including such fields as defence, medicine, and general science as well as agricultural

[11] Different agencies in different countries do not always strictly adhere to OECD standards in reporting science and technology indicators. For example, there may be some differences in the scope of research activity included (resulting in part from different views on what constitutes agriculture, in terms of sectoral coverage and the degree to which pre- and post-farm oriented research is included along with farm-focused research) and differences in what constitutes R&D.

science) grew quite rapidly in most OECD countries between 1981 and 1993, although more so for privately performed R&D (with an annual growth rate of 4.3 per cent) than for publicly performed R&D (with a growth rate of 3.5 per cent). The rates of growth of both publicly and privately performed research slowed in the late 1980s and early 1990s. In 1993 the private sector undertook US$190.8 billion of research, about two-thirds of all R&D performed throughout the OECD that year.

Distinguishing between the providers of funds for all R&D and those who performed the research provides additional insights into the links between the public and private sectors and their respective roles in the general R&D process. It also provides evidence about the net flow of public funds to private R&D providers. Table 6 shows that, in 1993, private agencies provided or performed US$190.8 billion of R&D and public agencies performed US$95.8 billion of R&D. However, in 1993, public *R&D spending* (US$120 billion) was considerably greater than public *R&D provision* (US$95.8 billion), while private R&D spending (US$166.7 billion) was correspondingly less than private R&D provision (US$190.8 billion). The imputed net flow of public funds to private research providers shows that a considerable amount of privately performed R&D was underwritten with public dollars.[12] But the amount of public funds flowing to private R&D declined in real terms in recent years from a peak of US$37.4 billion in 1987 to US$24.2 billion in 1993. The publicly funded share of privately performed R&D declined steadily over a longer period, falling from 22.4 per cent in 1981 to 12.7 per cent in 1993.

The recent decline in public support for private research has been widespread throughout the OECD countries, and the magnitude roughly corresponds to cutbacks in defence-related R&D. For example, France, the United States, and the United Kingdom—countries where the shares of total public research dollars spent on defence research in 1985 were 67.5, 51.0, and 32.5 per cent, respectively—account for the lion's share of the drop in public funds flowing to private R&D providers.[13]

---

[12] Unfortunately the data on public funding of R&D represent 'direct' government expenditures on research, and appear to exclude implicit transfers to the private sector through targeted tax concessions for R&D (OECD 1994, p.96).

[13] In 1986, for example, these three countries accounted for US$31.9 billion of the total of US$36.2 billion of public funds flowing to private R&D providers. In contrast, in 1993 they accounted for US$21 billion of a much reduced total of US$24.2 billion in public funds flowing to the private sector. Correspondingly, the public funds committed to defence R&D declined from a three-country total of US$42.9 billion (1985 international dollars) in 1986 to US$37.8 billion in 1993.

## 2.6 Private agricultural research

Table 7 provides our current best estimates of privately provided agricultural R&D and the private shares of total agricultural R&D spending from 1981 to 1993. A common perception is that agricultural research is primarily the domain of the public sector while research in other sections of the economy is the province of the private sector. But these new data indicate that

**Table 7** Privately performed agricultural R&D

| | (millions of 1985 international dollars) | | | | Annual growth (%) |
|---|---|---|---|---|---|
| | 1981 | 1986 | 1991 | 1993 | 1981–93 |
| *Privately performed agricultural R&D* | | | | | |
| Australia | 25.2 | *68.3* | *112.5* | 137.5[b] | 15.1 |
| Netherlands | 185.2 | 210.7 | 241.2 | 297.9 | 3.8 |
| New Zealand | 9.9 | 12.2[a] | 26.7 | 39.5 | 13.7 |
| United Kingdom | 404.2 | 473.6 | 593.5 | 614.3 | 5.0 |
| United States | 1 416.6 | 1 963.7 | 2 256.0 | 2 381.1[b] | 4.3 |
| *Subtotal (5)*[c] | *2 041.2* | *2 728.4* | *3 229.9* | *3 470.2* | *4.7* |
| Other (17)[g] | 1 953.5 | 2 691.9 | 3 419.5 | 3 560.3 | 5.5 |
| *Total (22)*[c g] | *3 994.7* | *5 420.3* | *6 649.4* | *7 030.5* | *5.1* |
| *Privately performed as a percentage of total agricultural R&D (percentages)* | | | | | |
| Australia | 8.2[d] | 17.9 | 26.8[e] | 30.3[b] | |
| Netherlands | 47.8 | 51.8 | 52.7 | 56.8[f] | |
| New Zealand | 6.9 | 9.1 | 19.5 | 26.9 | |
| United Kingdom | 52.1 | 55.8 | 62.0 | 62.4 | |
| United States | 46.6 | 52.1 | 52.7 | 53.7[d] | |
| *Subtotal (5)* | *43.9* | *49.3* | *51.7* | *53.0* | |
| Other (17)[g] | 38.6 | 43.5 | 46.6 | 46.8 | |
| *Total (22)*[g] | *41.1* | *46.2* | *48.9* | *49.6* | |

Notes: Italicised, country-specific data are interpolated. Data derived mainly from OECD's intramural business sector series. Calculated as the sum of R&D performed by industries classified as 'agriculture, forestry, and fisheries', 'food and beverages', and 10 per cent of total research performed by the 'chemical and pharmaceutical industries'. The 10 per cent share of total chemical R&D assigned to agriculture represents an approximate rule of thumb procedure that was chosen after consulting various other relevant sources. For comparability purposes, agricultural mechanisation R&D was excluded from the US private sector series obtained from USDA (1995). See footnote 2 for additional details on data coverage.

[a] 1987 figure.
[b] 1992 figure.
[c] 1981 sub-totals and totals exclude Greece and New Zealand; 1985 figure excludes Greece.
[d] 1973 figure.
[e] 1990 figure.
[f] 1994 figure.
[g] Figures in parentheses indicate the number of countries included in the respective totals.

Source: Pardey, Roseboom and Craig (1997).

privately performed R&D is a prominent feature of agricultural R&D in rich countries. Privately performed agricultural R&D increased from US$4 billion in 1981 to over US$7 billion in 1993, at an annual growth rate of 5.1 per cent, and now accounts for almost half of all developed-country agricultural R&D, while all science and technology research performed by the private sector grew at an annual rate of only 4.3 per cent. In contrast, publicly performed agricultural R&D increased comparatively slowly at an annual growth rate of 1.8 per cent.

The relative importance of private agricultural R&D in total agricultural R&D varies across the OECD countries. Among the five countries, in the United Kingdom, the private sector is estimated to perform over 60 per cent of all agricultural research, and in the Netherlands and the United States the private share is currently in excess of 50 per cent. Australia and New Zealand still have significantly smaller private involvement in agricultural research, but privately performed R&D is becoming much more important in both countries. In New Zealand, this is partly because the government agencies that previously performed public agricultural research have been partially privatised.

The data presented in table 8 indicate that private and public research facilities do different types of R&D. Approximately 12 per cent of private research is focused on farm-level technologies whereas over 80 per cent of public research has that orientation. Food and other post-harvest research accounts for 30 to 90 per cent of private agricultural R&D, and in countries like Australia, Japan, New Zealand, and the Netherlands, it is the dominant focus of privately performed research related to agriculture. Chemical research is of comparatively minor importance in Australia and New Zealand, but accounts for more than 40 per cent of private agricultural research in the United Kingdom and the United States and nearly three-quarters of private agricultural research in Germany.

Particular lines of private agricultural R&D are concentrated in particular countries. Japan, the United States, and France account for 33, 27, and 8 per cent, respectively, of all food processing research carried out by the private sector in the OECD countries. Chemical research related to agriculture is even more concentrated; the United States, Japan, and Germany account for 41, 20, and 10 per cent of all reported private-sector research.[14] This pattern of concentration of private agricultural research would not alter significantly if we also included counterpart research in developing countries.

[14] These data exclude Switzerland, whose share of agricultural chemical R&D is probably substantial but unlikely to place it in the top three performers.

**Table 8** Focus of public and private intramural agricultural R&D, 1993

| | Publicly performed | | Privately performed | | |
|---|---|---|---|---|---|
| | Agriculture | Food and kindred products | Agriculture | Food and kindred products | Animal health and agricultural chemicals |
| *Expenditures (millions of 1985 international dollars)* | | | | | |
| Australia | na | na | 36.7 | 87.4 | 13.4 |
| The Netherlands | 224.9 | 14.3 | 60.1 | 173.1 | 64.7 |
| New Zealand | 87.7 | 19.7 | 4.8 | 34.2 | 0.5 |
| United Kingdom | 325.6 | 45.1 | 106.2 | 211.2 | 296.9 |
| United States | na | na | 314.9 | 817.7 | 1 248.5 |
| *Subtotal (5)*[a] | *na* | *na* | *522.6* | *1 323.6* | *1 624.1* |
| Other OECD (16)[a] | na | na | 300.4 | 1 736.1 | 1 448.5 |
| *Total OECD (21)*[a] | *na* | *na* | *823.0* | *3 059.7* | *3 072.6* |
| *Shares of respective sub-totals (percentages)* | | | | | |
| Australia | na | na | 26.7 | 63.6 | 9.8 |
| The Netherlands | 94.0 | 6.0 | 20.2 | 58.1 | 21.7 |
| New Zealand | 81.7 | 18.3 | 12.1 | 86.5 | 1.4 |
| United Kingdom | 87.8 | 12.2 | 17.3 | 34.4 | 48.3 |
| United States | na | na | 13.2 | 34.3 | 52.4 |
| *Subtotal (5)*[a] | *na* | *na* | *15.1* | *38.1* | *46.8* |
| Other OECD (16)[a] | na | na | 8.6 | 49.8 | 41.6 |
| *Total OECD (21)*[a] | *na* | *na* | *11.8* | *44.0* | *44.2* |

Notes: See table 7. OECD 21 country total excludes Switzerland due to lack of data.
[a] Figures in parentheses indicate the number of countries included in the respective totals.
Source: Pardey, Roseboom and Craig (1997).

Contemporary cross-country evidence on private R&D is revealing, but for the United States more detailed time-series data are available (USDA 1995). The focus of private agricultural research in the United States has changed. In 1960, agricultural machinery and post-harvest food processing research accounted for over 80 per cent of total private agricultural R&D. By 1992, these areas of research collectively accounted for only 42 per cent of the total, the share of total private research directed towards agricultural machinery having declined from 36 per cent in 1960 to less than 12 per cent. Two of the more significant growth areas in private R&D have been plant breeding, and veterinary and pharmaceutical research. Spending on agricultural chemicals research grew most quickly, and now accounts for more than one-third of total private agricultural R&D. These data point to a dramatic shift in the pattern of publicly and privately performed agricultural R&D in the United States over the past three decades, similar to those reported by Thirtle, Piesse, and Smith (1997) for the United Kingdom.

## 3. Recent institutional changes in public agricultural R&D

Shifts in the organisation of public agricultural R&D institutions in Australia, the Netherlands, New Zealand, the United Kingdom, and the United States, especially on the funding side, reflect six inter-related issues: (a) trends towards using public funds to support more basic rather than more applied or 'near-market' research; (b) trends towards the joint funding of near-market research through the development of industry levies and other mechanisms; (c) revamped oversight and accountability mechanisms, and other changes in management of research resources; (d) measures for introducing competition among researchers to increase research productivity and as a means of allocating research resources; (e) measures to privatise, directly or indirectly, public agricultural research institutions; and (f) trends towards the rationalisation of public agricultural research facilities. These changes are linked to recent developments in agricultural policy and general R&D policy, and transformations of agriculture and the agricultural sciences themselves.

### 3.1 Overview of changes in public agricultural R&D institutions

Public agricultural research systems vary in terms of who funds, manages, and performs the research. R&D is carried out by a range of government departments (some with roles extending well beyond research and well beyond agriculture), some semi-public entities, and various university faculties and departments. The five countries reviewed in detail here have quite diverse institutional set-ups. The public agencies undertaking agricultural R&D in the United Kingdom, the Netherlands, and New Zealand are mostly administered by national government departments, while in Australia and the United States public agricultural R&D is supported by a mix of state and national institutions. The United States has national government facilities administered by the United States Department of Agriculture, while state-level R&D is carried out in experiment stations located in land-grant colleges. The US trend has involved relatively less spending on national research facilities and relatively more on state agricultural experiment stations (SAES).[15]

Public agricultural R&D systems have experienced various degrees of restructuring in recent years. In the Netherlands, New Zealand, and the United Kingdom, the public agencies involved in carrying out research have

[15] In 1971, US$2.06 was spent by the State Agricultural Experiment Stations (SAES) for every dollar spent on intramural R&D undertaken by the United States Department of Agriculture; in 1993, US$2.86 were spent by the SAESs for every federal dollar.

been substantially revamped. In England and Wales, as well as in the Netherlands, the agencies that perform public R&D were consolidated and in some important instances commercialised. In New Zealand, new Crown Research Institutes (CRIs) were established in an effort to develop a public 'market' for R&D services that distinguishes between buyers and sellers of such services. Comparatively little structural change has taken place in the public agencies that undertake agricultural R&D in Australia and the United States, although Australia's funding and management structures have recently been revised substantially.

The timing of reforms in each of the five countries has been closely linked to the advent of governments with more market-oriented, *laissez-faire* economic philosophies about the role of government in management of the economy. In the United Kingdom, for example, the Conservative government led by Margaret Thatcher was elected in 1979 and remained in power, with one change of leadership, until 1997. Reforms of UK public research institutions directed towards introducing market forces into the public research enterprise began in the early 1980s and continued into the early 1990s. In New Zealand, a reform government was elected in 1984 and confronted with a severe budget crisis; renovations of the New Zealand agricultural research system began less than one year later as part of a comprehensive package of policies. In Australia, the Hawke Labor government came to power in 1983 and, beginning in 1985, progressively initiated major changes in public agricultural research management that can be seen as part of more general micro-economic reforms. In the United States the conservative Reagan administration was elected in 1980, and cuts in the growth of public funding for research, including agriculture, followed in 1981 and 1982. And in the Netherlands a series of more market-oriented coalition governments were formed in the early 1980s.

### 3.2 Basic and applied research[16]

One important recent trend in the United States, the Netherlands and the United Kingdom has been the apparent redirection of research funds derived from general tax revenues towards basic research and away from applied research. This shift accords with the general public finance principle that public funds should be used to provide public goods. Reported patterns of

[16] Alston, Christian and Pardey (1997) argue that classifying research into 'basic', 'applied', or 'developmental' activities is generally subjective, usually difficult, and at times may be done in a self-serving fashion that throws doubt on the reported orientation. Moreover, these categories mean different things to different scientists and an economic evaluation of science may not find the distinctions made by scientists especially useful.

change are strikingly similar across all three countries, where the share of public agricultural R&D funds allocated to universities (that typically undertake research with a more basic orientation) has increased substantially.

The evidence in relation to Australia and New Zealand is less clear. In Australia, since R&D Corporations (RDCs) and Cooperative Research Centres (CRCs) have become more important in funding agricultural research, more funds probably have been directed towards applied research. In New Zealand, the creation of the Public Good Science Fund in 1992 was intended to signal a reallocation of public R&D resources to more general public good and public interest research. It is not at all clear, however, that resources within the New Zealand public agricultural R&D program have actually been redirected towards more basic research (Jacobsen and Scobie 1997).

### 3.3 Privatising previously public roles

A related development in the organisation and funding of agricultural research, common to all five countries, has been an increased emphasis on the role of the private sector and, in particular, industry and commodity groups in supporting agricultural research programs.

*Levy funds and matching arrangements*

One of the more dramatic examples of this trend is the evolution of Australian agricultural research policy since the mid-1980s. Legislation in 1985 and 1989 created RDCs to manage research funds generated by industry levies with dollar-for-dollar matching funds to be provided by the government up to a limit of 0.5 per cent of the gross value of industry production. These changes substantially increased the share of funds for publicly conducted agricultural R&D managed by the RDCs or their predecessors (Alston, Pardey and Smith 1997). They also increased the industry representation on the RDC boards and project selection committees. A more recent initiative may turn out to be even more important. The introduction of CRCs in the early 1990s, linking research by government, universities, and the private sector, has fostered a revitalised growth in total funding for agricultural R&D.

In the Netherlands, as in Australia, the principle of joint funding for experiment station and other agricultural research programs, by the agricultural sector and the government (on a dollar-for-dollar basis), was a key element of agricultural research policy for many years. Between 1950 and 1970, the joint-funding principle became less relevant but, during the late 1970s and 1980s, confronted by successive budget crises, the Netherlands

Ministry of Agriculture re-emphasised its importance. In addition, after 1980, the University of Wageningen was also encouraged to seek funding from industry sources for research projects. As a result, private funding, which represented less than 25 per cent of total university funds for agricultural research in the 1970s, accounted for over 40 per cent by the mid-1990s.

In New Zealand, statutory bodies (typically marketing boards) have used levies to support market development and research programs since the 1920s. In 1990, the New Zealand government passed the Commodity Levies Act under which industry groups were given authority to impose mandatory levies to fund sector-specific research and other (market development) activities. As a result, new commodity group funds have been established for several agricultural products such as Kiwi fruit and tomatoes.

In the United Kingdom, there is no parallel history of matching fund programs. However, in conjunction with the decision to reduce funding for near-market research, the Thatcher governments of the mid-1980s passed legislation enabling the creation of commodity-specific statutory bodies, funded by industry levies, to develop markets and fund commodity-specific applied research. These bodies were to have boards of directors whose membership would be dominated by industry representatives. Statutory bodies have now been established for all major agricultural commodities, but they only account for about 6 per cent of total public expenditure on agricultural research.

Developments in the United States have been less dramatic, more incremental, and by and large have not involved any major legislative changes. Private-sector funding for public agricultural research has generally increased since 1975, largely as a result of increased private funding for State Agricultural Experiment Station (SAES) operations. However, there is no evidence of any pressure to develop levy programs to fund agricultural R&D on a widespread or substantial basis.[17]

### *Pricing research*

A further issue in relation to the involvement of the private sector in the publicly funded agricultural research system is the pricing of research services. In each country, the private sector supports research conducted at public research institutes. In Australia, the Industry Commission recently argued that such establishments ought to price their services to cover all long-run costs of producing the privately commissioned research unless it

[17] As Lee *et al.* (1996) document, however, industry levies are used extensively to fund commodity promotion in California.

provides significant spill-over benefits (Industry Commission 1995). Some economists have questioned this view (Watson 1996). In the United Kingdom, New Zealand and the Netherlands, the question of full-cost pricing for the use of publicly funded agricultural research facilities has also become an important issue in the 1980s and 1990s as the share of private funding for such facilities has increased, and policies with respect to overhead charges at universities and ministry research facilities have become more formalised.

*Privatisation*

Explicit privatisation of agricultural research enterprises has been an important feature of the reorganisation of agricultural research only in the United Kingdom. Indirect privatisation of research, through opening up access to public funds for private and independent research institutes, has taken place in all five countries. In the United Kingdom, the direct privatisation of some agricultural research institutes in the late 1980s and early 1990s was partly the result of the government's economy-wide program to privatise many publicly owned enterprises, and its intent to stop funding and managing near-market research. In New Zealand, the government opted for the comprehensive introduction of a system of quasi-private public research institutes through the creation of the system of Crown Research Institutes for all research. However, although the new CRIs must now obtain support from a general contestable public fund, they do not operate under the profitability constraints that confront private facilities and seem, implicitly, to enjoy guaranteed access to the available pool of public funds (Jacobsen and Scobie 1997). In the Netherlands, a partial form of privatisation has been initiated. In the mid-1980s the government determined that agricultural research could be placed in the hands of the private sector. Since then, through a variety of mechanisms, agricultural research institutes previously funded and managed by the Ministry of Agriculture have been partially detached from its control and have become more reliant on private funding sources.

## 3.4 Rationalising government agricultural research

Changes in the scientific, economic, and political factors relating to agricultural science have created serious problems for managers of national research organisations: how should those agencies be restructured over time? The problem is challenging for any research agency, but is particularly acute in the public sector because of problems associated with rent seeking and policy inertia. Once public research institutes are created, the employees in those institutes establish formal or informal interest groups. The result is often tremendous inertia in publicly operated research organisations. During the late 1970s and the 1980s, circumstances arose in which the perceived costs of inefficiencies in public research systems became large, especially in the Netherlands and the United Kingdom. Thus, over this period, agricultural research in the Netherlands was continually reorganised and rationalised and the oversight process was streamlined, while in the United Kingdom the number of publicly funded research institutes fell by more than over half.

### 3.5 Managed competition

The introduction of managed forms of competition has been a feature of the allocation of public funds in all five countries, beginning in the mid-1980s. On balance, these changes have increased the amount of competition among researchers for those funds. In all five countries, the proportion of funds disbursed through block grants or formula funds has fallen while the proportion of funds disbursed through competitive or quasi-competitive grants processes has grown.

Although much has been said about moving towards competition, and away from formula funding or block grants, the actual movement has been uneven. New Zealand has moved fastest and farthest in this direction, but even there questions are still asked about how effective the resulting new institutions are and whether the rent-seeking costs outweigh the benefits. The United States has barely moved in this direction: in 1995, only US$101 million in a public agricultural R&D budget of US$3.0 billion was allocated through competitive grants (see, also, National Research Council 1994). The other countries are between these extremes, both in what they have done and what they have said they might do. As well as differing in the degree of movement towards more use of competitive processes for allocating research resources, each country has adopted its own institutions for allowing competition to operate. However, to a great extent, the competition has often been strictly based on *ex ante* claims, promised performance, rather than *ex post* assessments of what was actually delivered in the past. An important difference has been in the role for the agricultural industry to participate both as a provider of funds and in having a say as to criteria to be used to determine priorities.

A related issue has been the role of accountability processes. In several countries, the criteria for periodic reviews of block grants and the distribution of those grants among competing research programs and institutions have also tended to become more formal and more stringent and such reviews have become more frequent. In the United Kingdom, for example, since the late 1980s, all university departments have been individually assessed with respect to their research output once every five years. Within each discipline or sub-discipline, departments are ranked on a scale of 1 to 5 (where 1 is poor and 5 is excellent) and substantial research resources for the next five years are tied to these rankings. Similarly, in the Netherlands, since the late 1980s, the University of Wageningen (the country's only university centre for agricultural research) has been required to submit detailed four-year research plans once every two years for each department. Block grant funding is now conditional on approval of the University's overall plan of research and each department's proposal. In Australia, while there are no similar formal mechanisms, there has been a long history of evaluating research programs, both broadly at the national level, through the Industry Commission, and more narrowly by committees responsible for the use of levy funds, as well as by research performers. The creation of RDCs in the 1980s enhanced this process of accountability. In New Zealand, although new research priority-setting procedures were established in the late 1980s and early 1990s, there is little evidence that the new Crown Research Institutes, which now perform the majority of publicly funded agricultural research, have become subject to more stringent evaluation processes. Finally, in the United States, block grants of federal funds for SAES research continue to be determined by formula-funding mechanisms based on socioeconomic indicators such as population and are not tied to research performance.

## 3.6 Broadening research agendas

A common thread in the evolution of agricultural policy processes in developed economies has been the increase in the influence of non-farm interest groups on agricultural policy. These groups include providers of agricultural inputs, food processors, consumer groups, and environmental and conservation groups. In the case of European Union members, another increasingly important body has been the European Commission, both as a provider of funds and a regulatory agency. In various ways, these groups also have all become more important in the development of agricultural research policy.

The increasing influence of the environmental and conservation lobbies on the agricultural research agenda has been particularly noticeable during the past fifteen years. In the United States, the environmental lobby has greatly influenced the agricultural research agenda, leading to large publicly funded R&D programs devoted to issues such as sustainable agriculture and the maintenance of wetlands. The United Kingdom and the Netherlands have allocated substantial resources to the Ministries of Agriculture for research into environmental and conservation issues since the mid-1970s. Similar developments have also occurred in Australia.

A less widely recognised phenomenon has been the increased influence of the agribusiness lobby on agricultural R&D. Since the mid-1980s in the United Kingdom, food processors have been vocal on agricultural research oversight committees such as the Priorities Board, which in turn have recommended reallocations of public research resources to address issues of concern to that sector. A similar development has taken place in Australia, partly through the changed structure of the RDC boards and the development of CRCs with significant agribusiness involvement. In New Zealand, agribusiness representatives have also been given a larger role in determining the allocation of public agricultural research funds, and public funding for food-processing research has increased markedly in the mid-1990s.

The increasing importance of consumer groups has also been reflected in developments in agricultural research policy. For instance, funding for food-safety research has increased in both the United States and the United Kingdom, partly because of a series of health scares since the mid-1980s related to such things as salmonella in eggs, E. coli in meat, BST in milk, and mad cow disease. Thus, just as agricultural policy in general has become the province of more than just agricultural producer groups, so too has agricultural research policy.

## 4. Assessment

The crucial questions for economists concern whether or not the recent changes in public agricultural R&D have resulted in improvements in economic efficiency and economic welfare. More specifically, the issues involve whether changes have led to an improvement in efficiency in terms of the total quantity of research being undertaken; lower-cost sources of funds; better allocation of resources between competing programs or projects, having differing emphasis on commodities or natural resource management, or other areas of research focus; better allocation of research resources among institutions; better allocation between basic and applied research and extension, or farming versus processing research; more effective use of research funds and less waste in excessive administrative overhead or other transactions costs.

Reductions in growth rates for public agricultural R&D funding may be questioned in light of the broad array of empirical evidence that the rates of return associated with those investments have been relatively high. Most studies have reported annual rates of return well in excess of 30 per cent.[18] However, some recent findings suggest that, when lags between research and productivity effects are taken fully into account, previously very high estimates of real, long-run rates of return to public agricultural R&D investments (at least in the United States) may be reduced to about 10 per cent (Alston, Craig, and Pardey 1997), still high enough to justify the investments but not the bonanza that is often claimed.

Increasing the role of the private sector in the management of public agricultural R&D has also been an important theme over the past fifteen years. This has occurred either as a result of linking public and private funding through levy schemes, with the joint funds being managed by committees more heavily influenced by industry representatives (as in Australia, the Netherlands, and the United Kingdom), or through the appointment of industry representatives to committees with responsibilities for establishing research priorities. This is a double-edged sword with both potential costs and benefits. On the costs side, regulatory capture becomes a concern. When research boards that allocate public and private sector funds are dominated by industry representatives, public funds may be redirected to projects that benefit only sectoral interests or perhaps only a part of an industry (e.g., Ulrich, Furtan, and Schmitz 1986). In addition, more directed public–private ventures may crowd out industry research funds. Worse still, industry capture of research programs can result in perverse consequences (e.g., Constantine, Alston, and Smith 1994). On the other hand, especially when the focus is near-market research, increased input from the industry can reduce regulatory capture by the scientists or government bureaucrats, who may not always have the public good in mind when making resource allocation decisions. Researchers can thus become more responsive to industry needs and concerns and carry out more effective applied research programs.

In principle, increasing competition for research funds can be an effective device for revealing information to funders about both opportunities for research and comparative advantage in its execution. Competitive processes can reduce the costs of information and of research resource misallocation (Alston and Pardey 1996), but they can also involve higher transaction costs (Huffman and Just 1994). The challenge has been to devise institutions that

[18] For instance, in a recent summary, Fuglie *et al.* (1996, p. 28) report: 'Most studies that have estimated the aggregate social rate of return to research consistently found rates of return between 40 and 60 per cent.' In a forthcoming study, Alston, Marra, Pardey and Wyatt (1997) have documented results from some 141 studies that have estimated internal rates of return to agricultural R&D, ranging from -100 per cent to 724 323 per cent per year. Of these rates of return, 95 per cent fell between 11 and 321 per cent per year, and 90 per cent fell between 15 and 151 per cent per year.

will minimise the total costs of research decision-making, considering the invisible resource misallocation costs as well as the more obvious costs of competing for funds. Interestingly, in the United Kingdom, the process of five-year research productivity assessments for university departments represents a middle ground that attempts to appropriate the benefits of some degree of competition in allocating block grant funds without incurring the costs of requiring competition on a project-by-project basis for all research resources.

The shift towards creating a competitive research supply environment by moving away from very long-term contracts (tenure) for researchers to shorter-term contracts also has its potential pluses and minuses. The major potential gains are that (a) it is easier to remove 'dead wood' from the research system; (b) shorter-term contracts may provide incentives for greater research productivity among all researchers; and (c) research administrators may have greater flexibility in managing research resources. A potentially serious disadvantage is that the removal of long-term guarantees of employment may reduce incentives for competent and gifted individuals to embark on research careers that require large private investments in human capital. Perhaps insufficient attention has been given to the optimal structure of incentives for the long-run development and maintenance of productive research industries. It is certainly not entirely clear whether the short-term benefits associated with recent policy shifts in this respect outweigh any potential longer-term costs.[19]

The situation *vis-à-vis* rationalisation of public research facilities may be less ambiguous. To the extent that rationalisation has taken place in response to recent changes in scientific methods and to take advantage of new economies of size and scope, there have been clear economic efficiency gains. Where 'rationalisation' has simply operated as a synonym for 'reductions in public R&D investments', whether the changes have been good or bad turns on whether or not the rates of return on the investments were higher than the social opportunity cost of the funds.

Broadening the research agenda may have led to some benefits. Environmental and food safety issues are often public good issues, and market failures in research often accompany the more general market failures in these areas (e.g., Antle 1995; Alston, Anderson and Pardey 1995). Accordingly, many seem to believe that reallocations of public research resources to these issues and away from near-market research programs must enhance economic welfare (e.g, Ervin and Schmitz 1996). The answer to this question remains unclear, however, since no formal evidence is available on

[19] See Schultz (1977) and Wright and Zilberman (1993).

the pay-off to public R&D on environmental or food safety issues, and achieving a pay-off at all requires effective incentives to adopt results that yield social benefits, and lack of effective incentives is sometimes the central problem with such issues (see Alston and Pardey 1996).

To the extent that public resources have been diverted towards agribusiness and food processing research (as in the United Kingdom and New Zealand, and possibly in Australia), there is a further potential downside to the recent developments in agricultural research policy. It is by no means clear that projects funded in these areas more closely approximate public good projects than those they may have displaced in the area of farm productivity.[20] On *a priori* grounds, given that the farm sector is largely atomistic, while many agribusiness and food processing markets are characterised by relatively few firms with no clear *prima facie* evidence of market failure in research, this shift of research resources may have reduced rather than increased the rate of return to public research investments.

Clearly, then, there is considerable ambiguity about whether the changes in agricultural research policy implemented by developed countries since the early 1980s have led to net social benefits. The issues are essentially empirical and, to date, agricultural economists have not been able to provide many empirical answers. This is not to suggest that the agricultural economics profession has failed, but rather to argue that opportunities remain for agricultural economists to make important contributions to the agricultural policy debate and the formation of welfare-enhancing agricultural research policies. There are long and variable lags between changes in R&D policies and the realisation of their productivity and welfare consequences. It is too soon to attempt a complete accounting of the economic consequence of these contemporary changes in agricultural R&D funding and the accompanying institutional experiments. The investigation of these issues represents an important future agenda for research policy analysts.

## References

Alston, J.M., Anderson, J.R. and Pardey, P.G. 1995, 'Perceived productivity, foregone future farm fruitfulness, and rural research resource rationalization', in Peters, G.H. and Hedley, D.D. (eds), *Agricultural Competitiveness: Market Forces and Policy Choice*, proceedings of the twenty-second international conference of agricultural economists, Dartmouth, Aldershot, pp. 639–51.

Alston, J.M., Christian, J.E. and Pardey, P.G. 1997, 'Agricultural R&D investments and institutions in the United States', in Alston, J.M., Pardey, P.G. and Smith, V.H. (eds), *Paying for Agricultural Productivity*, IFPRI, Washington, DC, forthcoming, chapter 4.

[20] Scobie (1984) provides a clear and entertaining exposition of the arguments.

Alston, J.M., Craig, B.J. and Pardey, P.G. 1997, 'Dynamics in the creation and depreciation of knowledge, and the returns to public research', EPTD Discussion Paper, IFPRI, Washington, DC, forthcoming.

Alston, J.M., Harris, M.S., Mullen, J.D. and Pardey, P.G. 1997, 'Agricultural R&D policy in Australia', in Alston, J.M., Pardey, P.G. and Smith, V.H. (eds), *Paying for Agricultural Productivity*, IFPRI, Washington, DC, forthcoming, chapter 5.

Alston, J.M., Marra, M.C., Pardey, P.G. and Wyatt, T.J. 1997, *Research Returns Redux: A Meta-Analysis of Agricultural R&D Evaluations*, draft IFPRI Research Report, International Food Policy Research Institute, Washington, DC, in preparation.

Alston, J.M. and Pardey, P.G. 1996, *Making Science Pay: The Economics of Agricultural R&D Policy,* American Enterprise Institute Press, Washington, DC.

Alston, J.M., Pardey, P.G. and Smith V.H. (eds) 1997, *Paying for Agricultural Productivity*, IFPRI, Washington, DC, forthcoming.

Antle, J.M. 1995, *Choice and Efficiency in Food Safety Policy,* American Enterprise Institute Press, Washington, DC.

Baker, I., Baklien, A. and Watson, A.S. 1990, *A Review of Agricultural Research in Australia,* Department of Agriculture, Melbourne.

Baum, W.C. 1986, *Partners Against Hunger: Consultative Group on International Agricultural Research*, World Bank, Washington, DC.

Constantine, J., Alston, J.M. and Smith, V.H. 1994, 'Economic impacts of California's one variety cotton law', *Journal of Political Economy*, vol. 102, no. 5, pp. 66–89.

Ervin, D.E. and Schmitz. A. 1996, 'A new era of environmental management in agriculture', *American Journal of Agricultural Economics*, vol. 78, no. 5, pp. 1198–206.

Fuglie, K., Ballenger, N., Day, K., Klotz, C., Ollinger, M., Reilly, J., Vasavada, V. and Yee, J. 1996, *Agricultural Research and Development: Public and Private Investments under Alternative Markets and Institutions*, USDA-ERS-NRED Agricultural Economic Report no. 735, United States Department of Agriculture, Washington, DC, May.

Grantham, G. 1984, 'The shifting locus of agricultural innovation in nineteenth-century Europe: the case of the agricultural experiment stations', *Research in Economic History*, vol. 3, supplement, pp. 191–214.

Gryseels, G. and Anderson, J.R. 1991, 'International agricultural research', in Pardey, P.G., Roseboom, J. and Anderson, J.R. (eds), *Agricultural Research Policy: International Quantitative Perspectives*, Cambridge University Press, Cambridge, chapter 9.

Hayami, Y. and Yamada, S. 1975, 'Agricultural research organization in economic development: a review of the Japanese experience', in Reynolds, L.G. (ed.), *Agriculture in Development Theory*, Yale University Press, New Haven.

Heston, A., Summers, R., Nuxoll, D.A. and Aten, B. 1995, 'The Penn world table (mark 5): an expanded set of international comparisons, 1950–1988', Version 5.6, http://cansim.epas.utronto.ca:5680/pwt., released January 1995.

Huffman, W.E. and Just, R.E. 1994, 'Funding, structure, and management of public agricultural research in the United States', *American Journal of Agricultural Economics*, vol. 76, no. 4, pp. 744–59.

Industry Commission 1995, *Research and Development, Volumes 1 to 3*, Australian Government Publishing Service, Canberra.

Jacobson, V. and Scobie, G.M. 1997, 'Agricultural R&D policy in New Zealand', in Alston, J.M., Pardey, P.G. and Smith, V.H. (eds), *Paying for Agricultural Productivity*, IFPRI, Washington, DC, forthcoming, chapter 8.

Kerr, N.A. 1987, *The Legacy: A Centennial History of the State Agricultural Experiment Station, 1887–1987,* Missouri Agricultural Experiment Station, Colombia.

Lee, H., Alston, J.M., Carman, H.F. and Sutton, W. 1996, *Mandated Marketing Programs for California Commodities*, Giannini Foundation Information Series no. 96–1, University of California, Davis, Division of Agriculture and Natural Resources, Davis.

McLean, I.W. 1982, 'The demand for agricultural research in Australia: 1870–1914', *Australian Economic Papers*, vol. 21, no. 40, pp. 294–308.

Mullen, J., Lee, K. and Wrigley, S. 1996, *Agricultural Production Research Expenditure in Australia: 1953–1994,* Agricultural Economics Bulletin no. 14, NSW Agriculture, Orange, July 1996.

National Research Council 1994, *Investing in the National Research Initiative: An Update of the Competitive Grants Program in the U.S. Department of Agriculture*, National Academy Press, Washington, DC.

OECD 1994, *Frascati Manual 1993: Proposed Standard Practice for Surveys of Research and Experimental Development*, Organization for Economic Co-operation and Development, Paris.

OECD 1996, *Basic Science and Technology Indicators,* Organization for Economic Co-operation and Development, Paris.

Pardey, P.G., Alston, J.M., Christian, J.E. and Fan, S. 1997, *A Productive Partnership: The Benefits from U.S. Participation in the CGIAR*, unpublished draft report, International Food Policy Research Institute, Washington, DC.

Pardey, P.G., Roseboom, J. and Anderson, J. 1991, 'Regional perspectives on national agricultural research', in Pardey, P.G., Roseboom, J. and Anderson, J.R. (eds), *Agricultural Research Policy*, Cambridge University Press, Cambridge.

Pardey, P.G., Roseboom, J. and Craig, B.J. 1997, 'Agricultural R&D investments and impact', in Alston, J.M., Pardey, P.G. and Smith, V.H. (eds), *Paying for Agricultural Productivity*, IFPRI, Washington, DC, forthcoming, chapter 3.

Roseboom, J. and Rutten, H. 1997, 'Financing agricultural R&D in the Netherlands: the changing role of government', in Alston, J.M., Pardey, P.G. and Smith, V.H. (eds), *Paying for Agricultural Productivity*, IFPRI, Washington, DC, forthcoming, chapter 7.

Salmon, S.C. and Hanson, A.A. 1964, *The Principles and Practice of Agricultural Research*, Leonard Hill, London.

Schultz, T.W. 1977, *What Are We Doing to Research Entrepreneurship?,* Agricultural Economics Paper no. 77:14, University of Chicago, Chicago, 25 March .

Scobie, G.M. 1984, 'Agricultural research: a bit of back to basics', *The Agricultural Economist*, vol. 5, no. 3, pp. 10–11.

*The Economist* 1997, 'A survey of universities: the knowledge factory', *The Economist*, 4 October 1997.

Thirtle, C., Piesse, J. and Smith, V.H. 1997, 'Agricultural R&D policy in the United Kingdom', in Alston, J.M., Pardey, P.G. and Smith, V.H. (eds), *Paying for Agricultural Productivity*, IFPRI, Washington, DC, forthcoming, chapter 6.

True, A.C. and Crosby, D.J. 1902, *Agricultural Experiment Stations in Foreign Countries,* USDA Office of the Experiment Stations Bulletin no. 112, US Government Printing Office, Washington, DC.

Ulrich, A., Furtan, W.H. and Schmitz, A. 1986, 'Public and private returns from joint research: an example from agriculture', *Quarterly Journal of Economics*, vol. 101, no. 10, pp. 101–29.

USDA 1995, *AERI Updates: Agricultural Research*, AERI Update no. 5. revised, United States Department of Agriculture, Washington, DC.

Watson, A. 1996, 'The price of research: understanding the economics of charging for research', paper presented at the conference on *Global Agricultural Science Policy for the Twenty-First Century*, Melbourne, August 1996.

World Bank 1995, *World Tables*, Diskette version, World Bank, Washington, DC.
Wright, B.D. and Zilberman, D. 1993, 'Agricultural research structures in a changing world', in Weaver, R.D. (ed.), *U.S. Agricultural Research: Strategic Challenges and Options*, Agricultural Research Institute, Bethesda, MD.