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FINANCING AGRICULTURAL R&D IN RICH COUNTRIES: WHAT'S HAPPENING AND WHY

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ABSTRACT

Governments around the globe 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. These contemporary developments represent a break from previous patterns, which, since WWII, had seen a significant and steady expansion in the public funds provided for agricultural R&D. The growth rate of private-sector spending on agricultural research has slowed along with the growth of public spending in recent years, but the balance continues to shift toward the private sector. This paper presents a quantitative review of these funding trends and the considerable institutional changes that have accompanied them. We present and discuss new data for 22 OECD countries, provide additional data and institutional details for five of these countries, namely Australia, Netherlands, New Zealand, United Kingdom, and the United States, and conclude the paper with an assessment of these policy developments.

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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 world 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 perceive that we have entered a phase of general fiscal restraint, which, combined, with a more skeptical view of the social benefits from investments in science, has led to a tightening of resources available for research and calls for clearer justification for R&D funds and accountability for their use.

This paper 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

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[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,

public agricultural R&D policies and, taken together, they account for over 40 percent 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 skeptical view of the potential benefits from agricultural

Roseboom, and Craig (1997) provides an overview for the OECD as a whole. The current paper draws heavily on those items.

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.

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 longstanding 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 paper 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.

The remainder of the paper proceeds as follows. Section 2 focuses on funding. It begins with a brief account of the origins and development of publicly funded national agricultural research in developed economies between the middle of the nineteenth century and the present. Next, within the context of global changes in agricultural R&D and general science funding, we present new data on post-WWII trends in public and private agricultural R&D investments in the five countries of interest, in all OECD countries, and globally. We also examine the composition of agricultural R&D funded and performed by the public sector within the five countries, and by the private sector. Section 3 concerns changes in institutions. The discussion incorporates six inter-related themes of change in agricultural

R&D policy. Section 4 summarizes the changes in funding and institutions and section 5 concludes the paper with some brief speculation about the economic consequences.

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.[3] Its evolution has not been smooth or stable.

GENESIS AND EARLY DEVELOPMENT OF PUBLIC AGRICULTURAL RESEARCH

In many countries, formalized 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 have 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

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[2] One aspect that confounds international comparisons of agricultural R&D concerns differences in the meaning given to the term "agriculture." Agricultural production has become much more reliant on purchased chemicals, seeds, and machinery inputs, and a good deal of post-harvest processing and handling occurs beyond the farm gate. Many statistics fail to distinguish between farm-focused R&D, and R&D directed toward the input supply, food, and fibre processing sectors. In addition, as the environmental emphasis given to agricultural R&D has increased, nontraditional agencies have begun to carry out research of relevance to agriculture, while some agricultural research spills over to sectors beyond commercial agriculture (e.g., pest and weed control methods from agriculture are used in urban gardens and golf courses).

[3] It is noteworthy that public agricultural research on any substantial scale is a relatively recent phenomenon, a government enterprise that is no more than 150 years old in any country.

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 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 Möckern, 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. This provided the scientific basis for a second steady wave of expansion in public commitments to agricultural R&D during the first half of the twentieth century.[4]

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[4] These are only a few examples of the innovations in the biological and other basic sciences that underpinned technical progress in agriculture during the earlier part of this

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 internationally traded R&D goods and services.[5] 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 investments in science and technology research in general and agricultural research in particular.

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century. See Salmon and Hanson (1964) for the details of these discoveries.

[5] 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 Marakesh Agreement establishing the World Trade Organization — mandates the extension of intellectual property protection to plants.

In real terms, between 1945 and the mid-1970s, in most developed countries public expenditures on agricultural R&D grew more rapidly than in any other comparable period.[6] 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.

TRENDS IN PUBLIC AGRICULTURAL R&D FUNDING IN OECD COUNTRIES

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

[6] For example, between 1950 and 1970, in real terms public agricultural R&D expenditures increased at annual average growth rates of about 7 percent in Australia (Alston et al. 1997), about 7.4 percent in the United Kingdom (Thirtle, Piesse and Smith 1997), and about 2.8 percent 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 Ruttan (1997) and Jacobsen and Scobie (1997) report that both countries also substantially increased public investments in agricultural R&D between 1950 and 1970.

[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.

22 member countries of the OECD together account for over 90 percent 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 these five countries, which accounted for over 40 percent of public agricultural R&D outlays by OECD countries during this period, with trends in the other 17 OECD countries.

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

					Annual growth rates		
	1971	1981	1991	1993	1971-81	1981-93	1971-93
	(millions 1985 international dollars)				(percentages)		
Australia	238.7	281.9	307.8	315.8	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)[1]	*1,997.8*	*2,609.1*	*3,022.4*	*3,074.9*	*2.5*	*1.4*	*1.8*
Other OECD (17)[1]	2,300.2	3,104.3	3,919.1	4,054.9	2.9	2.1	2.6
Total OECD(22)[1]	*4,298.1*	*5,713.4*	*6,941.4*	*7,129.8*	*2.7*	*1.8*	*2.2*

Source: Pardey, Roseboom and Craig (1997).

[1] Number of countries in respective totals.

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 $4.3 billion to about $7.1 billion at an annual average growth rate of about 2.2 percent. However, this 22-year period can be divided into two distinct periods, 1971-1981 and 1981-1993. 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 percent; in the 1980s and early 1990s, the annual average growth rate fell by about one third, to 1.8 percent. The five countries of particular interest showed markedly lower average annual growth rates in public agricultural R&D expenditures (1.8 percent per year over the entire period, 2.5 percent between 1971 and 1981, and 1.4 percent between 1981 and 1993). The general pattern of growth was similar, however—faster in the 1970s and slower in the 1980s and early 1990s—but more pronounced in the five countries than in the OECD countries as a whole.

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 17 countries are examined. Over the period 1971-1993, total public agricultural R&D outlays in the 17 countries increased by over 75 percent from about $2.3 billion to almost $4.1 billion, at an annual average growth rate of 2.9 percent. In the first sub-period, 1971-1981, the annual average growth rate in public agricultural R&D for these 17 countries was 2.9 percent; in the second period, 1981-1993, it fell by more than one fourth, to 2.1 percent. Again, there is a similar pattern but the growth rate of public agricultural R&D expenditures fell by two fifths in the five selected countries, much more than in the other 17 OECD countries.

Among themselves, the five countries exhibited some important differences with respect to funding trends. In the United States, public agricultural R&D expenditures increased from about $1.2 billion in 1971 to just under $2.1 billion in 1993, an annual average growth rate of 2.3 percent—compared with 2.2 percent for all OECD countries, and 2.6

percent for the other 17 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 percent in the 1970s to 2.1 percent in the 1980s, was also very similar to those experienced in the other 17 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 percent and 1.6 percent, 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 Australia and the Netherlands, and absolute declines (i.e., negative growth) in public R&D spending in New Zealand and the United Kingdom over the period 1981 and 1993.

Among the other 17 OECD countries, only three countries—Belgium, Canada, and Greece—also experienced reductions in total public agricultural R&D spending over the period 1981-1993. 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 organization and management of public agricultural research than the U.S. government did.

The allocation of public agricultural research funds between universities and other institutions provides some indication of whether the public research portfolio has shifted towards basic research. 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 14 other OECD countries for which such data were available. In all of the five countries, between 1971 and 1993, the university shares of total public agricultural R&D spending increased. In Australia and New Zealand, the increases were very modest (from 10.7 percent to 11.6 percent and from 13.0 percent to 13.6 percent respectively), but in the other three countries, the increases were substantial. In the United Kingdom, the university share increased from 2.3 percent to 14.7 percent, in the Netherlands it increased from 14.9 percent to 31.9 percent, and in the United States it increased from 67.3 percent to 74.1 percent. In the other 14 OECD countries, the average share of public agricultural R&D funds changed little, from 27.5 percent to 28.0 percent 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 more basic research.

The annual rates of growth in public agricultural R&D expenditures in both the five countries and the other 17 OECD countries were quite small in the 1970s, compared with the annual growth rates of 7 to 8 percent 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 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 ensure security of future food and fiber supplies.

Table 2 University share of public agricultural R&D spending, 1971-93

	1971	1981	1991	1993
	(percentages)			
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[1]	67.3	67.5	74.0	74.1
Sub-total (5)[2]	*45.0*	*45.6*	*54.8*	*55.3*
Other OECD (14)[2]	27.5	25.6	28.2	28.0
Total OECD (19)[2]	*38.8*	*37.9*	*43.0*	*43.2*

Source: Pardey, Roseboom and Craig (1997).

[1] University research in the United States includes research undertaken by the State Agricultural Experiment Stations operated in conjunction with the state land-grant universities.
[2] Number of countries in respective totals.

The rapid growth rates in public agricultural R&D expenditures by OECD countries during the 1950s and 1960s were probably not sustainable over the very long run in economies that typically enjoy annual growth rates of between two and three percent in real economic output and also in agricultural productivity. It may therefore be reasonable to conclude that, by the beginning of the 1970s, in many countries publicly funded agricultural research had become a mature industry likely to enjoy only modest future expansion rather than an infant industry enjoying rapid expansion. This hypothesis, however, does not completely explain why, over the period 1981-1993, real public agricultural R&D expenditure growth rates declined on average by about a third in OECD countries, and by more in some. Section 3 considers other reasons.

GLOBAL PERSPECTIVES ON PUBLIC AGRICULTURAL EXPENDITURE TRENDS

The pattern of declines in growth rates of public agricultural R&D expenditures in the 1980s was not restricted to developed economies. Nor is it entirely restricted to agricultural R&D. Some perspective is provided by considering global agricultural R&D funding patterns, which we do next, and funding trends for general science and technology R&D, which follows.

Developing-Country Trends

Estimates of global public agricultural R&D expenditures, disaggregated by developing countries and developed countries, are presented in table 3. Between 1971 and 1991, public expenditures on agricultural R&D in developing countries increased from just under $3 billion to just over $8 billion, at an annual average growth rate of 5.1 percent. These expenditures grew most rapidly over the entire period in China (6.3 percent per year), other East Asia and Pacific Rim countries (7.3 percent per year) and West Asia and North Africa (4.3 percent 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 percent per year) and Latin America and the Caribbean (2.7 percent), 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 4.4 percent, but between 1981 and 1991 they grew at an annual rate of only 2.8 percent.

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 funded and conceived 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 centers took place largely under the auspices of the Consultative Group on

Table 3 Real public agricultural R&D spending, global, 1971-91

	1971	1981	1991
	(millions 1985 international dollars)		
Expenditures			
Developing countries	2,985.2	5,534.8	8,016.7
Sub-Saharan African	699.2	927.2	968.4
China	457.4	939.4	1,494.3
Asia and Pacific (excl. China)	861.5	1,922.4	3,501.6
Latin America and Caribbean	507.9	1,007.7	950.7
West Asia and North Africa	459.2	738.1	1,101.7
Developed countries	4,298.1	5,713.4	6,941.4
Total	*7,283.3*	*11,248.2*	*14,958.1*
	1971-81	1981-91	1971-91
	(percentages)		
Average annual growth rates			
Developing countries	6.4	3.8	5.1
Sub-Saharan African	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	7.2	-1.1	2.7
West Asia and North Africa	4.3	4.0	4.8
Developed countries	2.7	1.7	2.3
Total	*4.4*	*2.8*	*3.6*

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

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 1991 series is the basis for the revised and updated ASTI data reported in the current table.

International Agricultural Research (CGIAR), which was established in 1971.[8] 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 centers or through contributions to agencies such as the World Bank, the Asian Development Bank, and the European Union.[9] 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 percent per year as the CGIAR system expanded to include more centers 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 percent per year between 1985 and 1991 and by only 0.5 percent 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.

[8] In 1996, the CGIAR spent $326 million, less than two percent of the public investment in agricultural R&D worldwide. For more details on institutional developments related to the CGIAR see Baum (1986), Anderson and Gryseels (1991), and Pardey et al. (1997). Anderson and Gryseels (1991) identify a further 17 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 Coopéracion 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 $368 million on R&D.

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

Agricultural Research Intensity Ratios

Public agricultural research intensity ratios (ARIs), computed by dividing public agricultural R&D expenditures by the value of agricultural output, are presented in table 4 for 20 OECD countries and all developing countries. In most developed countries, public agricultural R&D intensities increased throughout the period 1971-1992, including the 1980s and early 1990s. In the 20 OECD countries for which such ARIs could be computed, on average public ARIs increased from $1.47 per $100 of agricultural output in 1971 to $1.83 in 1981, $2.30 in 1991, and $2.48 in 1992. Among the five countries, on average a similar pattern emerges. The average ARI for the five countries increased from $1.87 in 1971 to $2.01 in 1981 and $2.52 in both 1991 and 1992. However, substantial differences can be seen among the countries. In New Zealand, for example, where historically public ARIs have been relatively high, the public ARI increased from $3.46 in 1971 to $4.11 in 1981, but in response to cuts in total funding, fell back to $3.62 in 1992. The public ARIs for the Netherlands and United Kingdom also exhibit similar patterns. In contrast, the public ARI for the United States barely increased, from $1.61 in 1971 to $1.63 in 1981, but then increased quite substantially to $2.25 by 1991. Similarly, in Australia, the public ARI increased from $2.82 in 1971 to $3.02 in 1981 and then rose quite sharply to $3.88 in 1992. Differences in the scales of their agricultural output, coupled with economies of scale and scope in the agricultural sciences, might account in part for why the countries with smaller agricultural sectors typically have higher public ARIs. The United States, with by far the largest agricultural output, has consistently had by far the smallest public ARI among the five countries.

Table 4 Spending ratios for publicly performed agricultural research, 1971-92

	1971	1981	1991	1992
	(percentages)			
Australia	2.88	3.02	4.07	3.88
The Netherlands	2.20	3.19	2.72	3.03
New Zealand	3.46	4.11	3.80	3.62
United Kingdom	2.23	3.33	3.11	3.32
United States	1.61	1.63	2.25	2.22
Subtotal (5)[1]	*1.87*	*2.01*	*2.52*	*2.52*
Other OECD (15)[1]	1.23	1.69	2.30	2.45
Total developed countries (20) [2]	*1.47*	*1.83*	*2.39*	*2.48*
Developing countries	*0.40*	*0.51*	*0.51*	*na*

Source: Pardey, Roseboom and Craig (1997).

[1] Number of countries in respective totals.
[2] Developed country total includes 20 OECD countries, excluding Switzerland and Sweden due to lack of agricultural GDP data.

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 5 for the period 1981-1993. In addition, table 5 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.

Table 5 Real overall public R&D spending in OECD countries, 1981-93

	1981	1991	1992	1993
		(percentages)		
Total publicly performed R&D relative to total output				
Australia	0.84	1.00 [1]	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)[2]	*0.82*	*0.85*	*0.85*	*0.84*
Other OECD (17)[2]	0.74	0.84	0.86	0.89
Total OECD (22)[2]	*0.78*	*0.85*	*0.86*	*0 .87*
		(billions 1985 international dollars)		
Public funding for all R&D				
Total OECD (22)[2]	91.6	120.8	na	120.0

Source: Pardey, Roseboom and Craig (1997).

[1] 1990 figure.
[2] Number of countries in respective totals.

Between 1981 and 1993, in aggregate in the 22 OECD countries, public funding for all science and technology R&D increased from $91.6 billion to $120.0 billion at an annual average growth rate of 2.4 percent. Over the same period, as noted above, public funding for agricultural R&D by OECD countries increased by about 1.8 percent per year. The average science and technology research intensity ratio for all 22 OECD countries was 0.78 percent in 1981 and 0.87 percent in 1993, increasing by a much smaller proportion than the ARI for 20 OECD countries, which rose from 1.83 in 1981 to 2.48 percent in 1992 (table 4).

According to these research intensity measures, agriculture has been treated relatively favorably in most developed countries with respect to the provision of public R&D funds over the recent past. However, this comparison masks 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 6 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 budget declined from 8.9 percent in 1981 to 7.4 percent in 1993, a proportional decrease of almost 17 percent. 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 percent to 6.6 percent but, again, these average data disguise considerable differences among 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 percent to 6.6 percent in the United Kingdom and from 6.2 percent to 5.6 percent 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 percent to 14.8 percent in Australia, from 49.1 percent to 35.5 percent in New Zealand, and from 14.5 percent in 1981 to 12.4 percent 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

Table 6 Agriculture's share of public R&D spending in OECD countries, 1981-93

	1981	1986	1991	1993
		(percentages)		
Australia	19.9	18.0	14.1	14.8
Netherlands	14.5	12.4	12.0	12.4 [1]
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 [1]
Subtotal (5)[1]	*7.6*	*6.7*	*6.7*	*6.6*
Other OECD(17)[1]	10.3	9.6	8.5	8.3
Total OECD (22)[1]	*8.9*	*8.1*	*7.6*	*7.4*

Source: Pardey, Roseboom and Craig (1997).

[1] Number of countries in respective totals.

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 defense research.

PRIVATE-PUBLIC LINKAGES IN 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 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 allows policy insights to be drawn from the data. The data reported in table 7 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.[10] 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 defense, medicine, and general science as well as agricultural science) grew quite rapidly in most OECD countries between 1981 and 1993, although more for privately performed R&D (with an annual growth rate of 4.3 percent) than for publicly performed R&D (with a growth rate of 3.5 percent). While 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 $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 about the linkages between the public and private

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[10] Agricultural research is taken here to include crop, livestock, forestry and fisheries research. See OECD (1994) for additional definitional details related to the compilation of science indicators.

[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 (due in part to 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.

Table 7 R&D by performer and source of funds

	1981	1986	1991	1993	Annual growth 1981-93
	(billions 1985 international dollars)				(percentages)
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

Source: Pardey, Roseboom and Craig (1997).

Note: Derived from gross expenditure on R&D (GERD) data included in table 1 of OECD (1996). Data include 22 OECD countries.

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 7 shows that, in 1993, private agencies provided or performed $190.8 billion of R&D and public agencies performed $95.8 billion of R&D. However, in 1993, public *R&D spending* ($120 billion) was considerably greater than public R&D *provision* ($95.8 billion), while private R&D *spending* ($166.7 billion) was corresponding less than private R&D *provision* ($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 has declined in real terms in recent years from a peak of $37.4 billion in 1987 to $24.2 billion in 1993. The publicly funded share of privately performed R&D has declined steadily over a longer period, falling from 22.4 percent in 1981 to 12.7 percent 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 defense-related R&D. For example, France, the United States, and the United Kingdom—countries where the shares of total public research dollars spent on defense research in 1985 were 67.5, 51.0, and 32.5 percent respectively—account for the lions' share of the drop in public funds flowing to private R&D providers.[13]

PRIVATE AGRICULTURAL RESEARCH

Table 8 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

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[12] Unfortunately the data on public funding of R&D represent "direct" government expenditures on research and appears 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 $31.9 billion of the total of $36.2 billion of public funds flowing to private R&D providers. In contrast, in 1993 they accounted for $21 billion of a much reduced total of $24.2 billion in public funds flowing to the private sector. Correspondingly, the public funds committed to defense R&D declined from a three-country total of $42.9 billion (1985 international dollars) in 1986 to $37.8 billion in 1993.

Table 8 Privately performed agricultural R&D

	1981	1986	1991	1993	Annual growth 1981-93
	(millions 1985 international dollars)				(percentages)
Privately performed agricultural R&D					
Australia	25.2	*68.3*	*112.5*	137.5 [2]	15.1
Netherlands	185.2	210.7	241.2	297.9	3.8
New Zealand	9.9	12.2 [1]	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 [2]	4.3
Subtotal [3]	*2,041.2*	*2,728.4*	*3,229.9*	*3,470.2*	*4.7*
Other (17) [7]	1,953.5	2,691.9	3,419.5	3,560.3	5.5
Total (21) [3,7]	*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 [4]	17.9	26.8 [5]	30.3 [2]	
Netherlands	47.8	51.8	52.7	56.8 [6]	
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 [4]	
Subtotal	*43.9*	*49.3*	*51.7*	*53.0*	
Other (17) [7]	38.6	43.5	46.6	46.8	
Total (22) [7]	*41.1*	*46.2*	*48.9*	*49.6*	

Source: Pardey, Roseboom and Craig (1997).

Note: Italicized figures 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 percent of total research performed by the "chemical and pharmaceutical industries." The agricultural chemical series was constructed using an approximate rule of thumb procedure that was chosen after consulting various other relevant sources. For comparability purposes, agricultural mechanization R&D was excluded from the U.S. private sector series.

[1] 1987 figure.
[2] 1992 figure.
[3] 1981 sub-totals and totals exclude Greece and New Zealand; 1985 figure excludes Greece.
[4] 1973 figure.
[5] 1990 figure.
[6] 1994 figure.
[7] Number of countries in respective totals.

perception is that agricultural research is primarily the domain of the public sector while research in other sectors of the economy are the province of the private sector. But these new data indicate that privately performed R&D is a prominent feature of agricultural R&D in rich countries. Privately performed agricultural R&D increased from $4 billion in 1981 to over $7 billion in 1993, at an annual growth rate of 5.1 percent, 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 percent. In contrast, publicly performed agricultural R&D increased comparatively slowly at an annual growth rate of 1.8 percent.

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 percent of all agricultural research, and in the Netherlands and the United States the private share is currently in excess of 50 percent. 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 privatized.

The data presented in table 9 indicate that private and public research facilities do different types of R&D. Approximately 12 percent of private research is focused on farm-level technologies whereas over 80 percent of public research has that orientation. Food and other post-harvest research accounts for 30 to 90 percent of private agricultural R&D, and in countries like Australia, Japan, New Zealand, and the Netherlands, it is the dominant focus

Table 9 Focus of public and private intramural agricultural R&D, 1993

	Publicly performed		Privately performed		
	Agriculture	Food & kindred products	Agriculture	Food & kindred products	Animal health and agricultural chemicals
			(millions 1985 international dollars)		
Expenditures					
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)[1]	*na*	*na*	*522.6*	*1,323.6*	*1,624.1*
Other OECD (16)[1]	na	na	300.4	1,736.1	1,448.5
Total OECD (21)[1]	*na*	*na*	*823.0*	*3,059.7*	*3,072.6*
			(percentages)		
Shares of respective sub-totals					
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)[1]	*na*	*na*	*15.1*	*38.1*	*46.8*
Other OECD (16)[1]	na	na	8.6	49.8	41.6
Total OECD (21)[1]	*na*	*na*	11.8	*44.0*	*44.2*

Source: Pardey, Roseboom and Craig (1997).

Note: See table 8. OECD 21 country total excludes Switzerland due to lack of data.

[1] Number of countries in respective totals.

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 percent of private 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 percent 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 represent 41, 20, and 10 percent 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.

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 research in the United States has changed. In 1960, agricultural machinery and post-harvest food processing research accounted for over 80 percent of total private agricultural R&D. By 1992, these areas of research collectively accounted for only 42 percent of the total, the share of total private research directed toward agricultural machinery having declined from 36 percent in 1960 to less than 12 percent. 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

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

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

In this section, we describe major shifts in the organization of public agricultural R&D institutions in Australia, the Netherlands, New Zealand, the United Kingdom and the United States, emphasizing the funding side. The discussion is organized around a number of themes that 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 check-offs 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 privatize, directly or indirectly, public agricultural research institutions, and (f) trends towards the rationalization of public agricultural research facilities. These changes are linked to the recent developments in agricultural policy and general R&D policy, and transformations of agriculture itself.

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 setups. The government agencies in the United Kingdom, the Netherlands, and New Zealand are mostly administered by national 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 (i.e., the USDA) with the state-level R&D being carried out in experiment stations located in land-grant colleges. The U.S. trend has involved relatively less spending in national research facilities and relatively more by 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 been substantially revamped. In England and Wales, as well as in the Netherlands, the agencies that perform public R&D have been consolidated and in some important instances commercialized. In New Zealand, new Crown Institutes have been 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

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[15] In 1971, $2.06 was spent in the SAESs for every dollar spent on intramural R&D undertaken by the USDA; in 1993, the ratio was $2.86 state dollars for every federal dollar.

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 England, 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 U.K. public research institutions directed toward 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 1981 and progressively initiated major changes in public agricultural research management, beginning in 1985, that can be seen as a part of more general microeconomic 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.

Since the early 1980s, significant changes have been made to the ways in which publicly funded agricultural research is organized and managed in Australia, the Netherlands, New Zealand, and the United Kingdom; less radical and less comprehensive shifts have occurred in the United States, perhaps because of the somewhat independent role of each state in funding and executing public agricultural research.

BASIC AND APPLIED RESEARCH

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 change are strikingly similar across all three countries and, in all three countries, the share of public agricultural R&D funds allocated to universities has increased substantially.[16]

The evidence in relation to Australia and New Zealand is less clear. In Australia, since R&D Corporations (RDCs) and Cooperative Research Centers (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 pubic good and public interest research. But it is not at all clear that resources within the New Zealand public agricultural R&D program have actually been redirected towards more basic research.

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[16] Alston, Christian and Pardey (1997) argue that classifying research into "basic," "applied,"or "developmental" activities is generally subjective and usually difficult: these categories mean different things to different scientists and an economic evaluation of science may not find the distinctions made by scientists especially useful. Moreover, some scientists may simply report their work in ways that enhance its prospects of being funded rather than reflect the nature of the work actually underway.

PRIVATIZING PREVIOUSLY PUBLIC ROLES

A related development in the organization 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.

Check-off (levy) Funds

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 percent of the gross value of industry production. These changes increased the share of funds for publicly conducted agricultural production R&D, managed by the RDCs or their predecessors, from 19 percent in 1985 to 47 percent in 1994. They also increased the industry representation on the RDC boards and project selection committees, disproportionately, some would say. 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 revitalized growth in total funding, and some would say a sharpening of the focus of agricultural and other 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 reemphasized 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 percent of total university funds for agricultural research in the 1970s, accounted for over 40 percent by the mid-1990s.

In New Zealand, statutory bodies (typically marketing boards) have used check-offs 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 kiwifruit 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 six percent of total public expenditures 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 check-off 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. The Australian Industry Commission recently expressed serious concerns about the need for such establishments to price their services to cover all long-run costs of producing the privately commissioned research unless it provides significant spill-over benefits (Industry Commission 1995).[18] 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 formalized.

Privatization

Explicit privatization of agricultural research enterprises has only been an important feature of the reorganization of the NARS in the United Kingdom. Indirect privatization of

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[17] Such means are used extensively to fund commodity promotion, however—see Lee et al. (1996).

[18] Also, see Watson (1997).

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 privatization of some agricultural research institutes in the late 1980s and early 1990s was partly the result of the government's economy-wide program to privatize 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 (CRIs) 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 privatization 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.

RATIONALIZING GOVERNMENT AGRICULTURAL RESEARCH

The dynamic nature of the scientific, economic and political factors related to agricultural science has created a serious problem for managers of national research organizations: 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 organizations, that is only overcome in times of crisis when the perceived opportunity costs of preserving the status quo become too large.[19]

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 reorganized and rationalized and the oversight process was streamlined, while in the United Kingdom the number of publicly funded research institutes declined by over half.

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 decreased while the proportion of funds disbursed through competitive or quasi-competitive grants processes has increased.

Although much has been said about moving towards competition, and away from formula funding or block grants, the actual movement in that direction has been uneven. New Zealand has moved fastest and farthest in this direction, but even still there are questions

[19] Becker (1983) discusses this phenomenon in a more general context.

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 $101 million in a public agricultural R&D budget of $3.0 billion was allocated through competitive grants (see also National Research Council 1994). The other countries are between these extremes, in both 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. 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. 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.

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 between 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 center 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 check-off 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 Institutes which 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.

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 recognized 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 England, 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. SUMMARY OF POLICY DEVELOPMENTS

In many developed countries agricultural research policy has changed importantly over the past fifteen years. In most OECD countries, annual growth rates in real public funding for agricultural R&D declined quite substantially from over 2.5 percent to about 1.8 percent, and in five of the 22 OECD countries for which we have data, total funding declined. Moreover, agriculture's share of the public budget for all R&D also declined.

Several factors have contributed to these reductions in public agricultural R&D expenditure growth rates, and the relative importance of agricultural R&D in public R&D portfolios in developed countries. In many countries, in the 1980s public funding for agricultural research was curtailed or its expansion moderated because of generally tight government budgets. In addition, public spending on all R&D became subject to sharper scrutiny as people became somewhat more skeptical of the potential social benefits of scientific research. In the early 1980s, this was a particular problem for agriculture in several countries where, as a result of agricultural price and income policies, large surpluses of some agricultural commodities existed (for example, the European Union and the United States). At about the same time, governments with more market-oriented economic management philosophies came to power in several countries, governments that were particularly skeptical about the appropriateness of using general government funds for very applied, near-market research that most obviously benefited relatively small producer groups. Moreover, in several countries, because of political redistricting, the absolute decline of national agricultural workforces, and the relative decline of the agricultural sector's contribution to total economic activity, the political influence of farm lobbies had also declined. At the same time, and for a variety of reasons, "non-traditional" interest groups such as environmental, agribusiness and food processing lobbies became more influential with respect to agricultural policy, including agricultural research policy.

The effects of the change in the agricultural policymaking environment have not been limited to impacts on public agricultural R&D expenditures. In at least three of the five countries examined in more detail in this study, substantive changes have been made in the nature of the research funded from the public purse. A larger proportion of public funds is now being allocated to more-basic research while funding for more-applied or near-market research has increasingly become the responsibility of individual firms or commodity groups using industry levies or check-offs—either entirely, as in the United Kingdom, or partially, as in Australia and the Netherlands where commodity group check-off funds or levies are matched in whole or in part by general government funds.

Another important feature of the changes that have taken place in agricultural research policy is the privatization of previously public roles, not only with respect to the funding of agricultural research but also with respect to its performance. Private R&D firms have been given more opportunities to bid for publicly funded projects, some public research institutions have been explicitly privatized, and others have been given a mandate to sell their research services to private firms (for example, universities and government agricultural technology transfer or extension agencies). The consequence has been that the demarcation lines between public and private agricultural research have become more blurred.

At the same time, in response to general budgetary pressures, an increased focus on economic efficiency in government, and changes in scientific methods, in many countries public research facilities have been rationalized, and in most countries management and employment structures have been changed to provide incentives for increased accountability on the part of research institutions and individual researchers. As part of this process, on economic efficiency grounds, several countries have endeavored to create institutions that make for more competition among researchers for public research funds.

Finally, the public agricultural R&D agenda has been broadened beyond traditional agricultural productivity issues to include issues concerning the environment, food safety, agribusiness, food processing, forestry and fisheries. This has come about partly because of the increasing influence of non-traditional lobbying groups on agricultural policy and partly because of a decline in the political influence of the farm sector.

5. 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. In turn, the questions concern whether the 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 among competing programs or projects, having differing emphasis among 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. The list of potential dimensions for efficiency gains goes on. We cannot answer many of these questions.

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 percent.[20] 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 percent (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 check-off schemes, with the joint funds

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[20] 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 percent." 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 percent to 724,323 percent per annum. Of these rates of return, 95 percent fell between 11 and 321 percent per annum and 90 percent of them fall between 15 and 151 percent per annum.

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 also may not always have the public good in mind in 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 research opportunity and comparative advantage in its execution. As argued by Alston and Pardey (1996), competitive processes can reduce the costs of information and of research resource misallocation; but as argued by Huffman and Just (1994), competitive processes also can involve higher transaction costs. Of course both ideas are correct. The challenge has been to devise institutions that will minimize 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 (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.[21]

The situation vis-a-vis rationalization of public research facilities may be less ambiguous. To the extent that rationalization 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 “rationalization” has simply operated as a

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

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 marginal social opportunity cost of 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 even this question remains unclear, however, since no formal evidence is available on the payoff to public R&D into environmental or food safety issues, and achieving a payoff 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.[22] On a priori grounds, given that the farm sector is largely atomistic, while many agribusiness and food processing markets are characterized by relatively few firms with no clear prima

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

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

Alston, J.M., J.R. Anderson and P.G. Pardey. 1995. Perceived productivity, foregone future farm fruitfulness, and rural research resource rationalization. In G.H. Peters and D.D. Hedley eds. Agricultural competitiveness: market forces and policy choice, proceedings of the twenty second international conference of agricultural economists, 639-651, Aldershot, Dartmouth.

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

Alston, J.M., P.G. Pardey, and V.H. Smith, eds. 1997. *Paying for Agricultural Productivity*, IFPRI, book length manuscript, forthcoming.

Alston, J.M., J. E. Christian, and P.G. Pardey. 1997. Agricultural R&D investments and institutions in the United States. Chapter 4 in J.M. Alston, P.G. Pardey, and V.H. Smith, eds. *Paying for Agricultural Productivity*, IFPRI, book length manuscript, forthcoming.

Alston, J.M., M.S. Harris, J.D. Mullen, and P.G. Pardey. 1997. Agricultural R&D policy in Australia. Chapter 5 in J.M. Alston, P.G. Pardey, and V.H. Smith, eds. *Paying for Agricultural Productivity*, IFPRI, book length manuscript, forthcoming.

Alston, J.M., M.C. Marra, P.G. Pardey, and T.J. Wyatt. 1997. Research returns redux: A meta-analysis of agricultural R&D evaluations. Draft IFPRI Research Report, Washington, D.C.: International: IFPRI, forthcoming.

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

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

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

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

Becker, G.S. 1983. A Theory of competition among pressure groups for political influence. *Quarterly Journal of Economics* 98 (August): 371-400.

Constantine, J., J.M. Alston, and V.H. Smith. 1994. Economic impacts of California's one variety cotton law. *Journal of Political Economy* 102 (October): 66-89.

Ervin, D.E. and A. Schmitz. 1996. A new era of environmental management in agriculture. *American Journal of Agricultural Economics* 78 (5) (December): 1198-1206.

Fuglie, K., N. Ballenger, K. Day, C. Klotz, M. Ollinger, J. Reilly, V. Vasavada, and J. Yee. 1996. Agricultural research and development: Public and private investments under alternative markets and institutions. USDA-ERS-NRED Agricultural Economic Report No. 735. May. Washington, D.C.: U.S. Department of Agriculture.

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

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

Huffman, W.E. and R.E. Just. 1994. Funding, structure, and management of public agricultural research in the United States. *American Journal of Agricultural Economics* 76 (4) (November): 744-59.

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

Jacobson, V. and G.M. Scobie. 1997. Agricultural R&D policy in New Zealand. Chapter 8 in J.M. Alston, P.G. Pardey, and V.H. Smith, eds. *Paying for Agricultural Productivity*, IFPRI, book length manuscript, forthcoming.

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

Lee, H., J.M. Alston, H.F. Carman, and W. Sutton. 1996. Mandated marketing programs for California commodities. Giannini Foundation Information Series No. 96-1. University of California, Davis, Division of Agriculture and Natural Resources, August.

McLean, I.W. 1982. The demand for agricultural research in Australia: 1870-1914. *Australian Economic Papers* 21: 294-308.

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

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

Organization for Economic Co-operation and Development. 1994. *Basic Science and Technology Indicators*. Paris.

Pardey P.G., J. Roseboom, and B.J. Craig. 1997. Agricultural R&D investments and impact. Chapter 3 in J.M. Alston, P.G. Pardey, and V.H. Smith ,eds. *Paying for Agricultural Productivity*, IFPRI, book length manuscript, forthcoming.

Pardey, P.G., J.M. Alston, J.E. Christian, and S. Fan. 1997. A productive partnership: The benefits from U.S. participation in the CGIAR. Unpublished draft report. Washington, D.C.

Roseboom, J. and H. Rutten. Financing agricultural R&D in the Netherlands: The changing role of government. Chapter 7 in J.M. Alston, P.G. Pardey, and V.H. Smith, eds. *Paying for Agricultural Productivity*, IFPRI, book length manuscript, forthcoming.

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

Schultz, T.W. 1977. What are we doing to research entrepreneurship? Agricultural Economics Paper No. 77 (14) March 25, 1977. University of Chicago.

Scobie, G.M. 1984. Agricultural research: A bit of back to basics. *The Agricultural Economist* 5 (3) (1984): 10-11.

Thirtle, C., J. Piesse, and V.H. Smith. 1997. Agricultural R&D policy in the United Kingdom. Chapter 6 in J.M. Alston, P.G. Pardey, and V.H. Smith, eds. *Paying for Agricultural Productivity*, IFPRI, book length manuscript, forthcoming.

True, A.C. and D.J. Cosby. 1902. Agricultural experiment stations in foreign countries. USDA Office of the Experiment Stations Bulletin No. 112, Washington, D.C.: U.S. Government Printing Office.

Ulrich, A., W.H. Furtan, and A. Schmitz. 1986. Public and private returns from joint research: An example from agriculture. *Quarterly Journal of Economics* 101 (10) (February): 101-29.

U.S. Department of Agriculture. 1995. AERI updates: Agricultural research. AERI Update No.5. revised. Washington, D.C.

Watson, A.S. 1997. The price of research: Understanding the economics of charging for research. Chapter in J.M. Alston and P.G. Pardey, eds. *Agricultural Science Policy: Changing Global Agendas*, book-length manuscript, forthcoming.

Wright, B.D. and D. Zilberman. 1993. Agricultural research structures in a changing world. In R.D. Weaver, ed. *U.S. Agricultural Research: Strategic Challenges and Options*, Bethesda, Md.: Agricultural Research Institute.