

ANNEX E7

PITA Project: Policy Influences on Technology for Agriculture:
Chemicals, Biotechnology and Seeds

United Kingdom PSREs in Agrochemicals,
Seeds and Plant Biotechnology

Annex E 7

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Introduction to the PITA Project

Technological innovation in the agrochemical, biotechnology and seeds industries and in associated public sector research establishments (PSREs) has the potential to deliver more socially and environmentally sustainable farming systems and to improve the quality of life of citizens in Europe. This is particularly true of farms on the most fertile land. However, although policies developed in different areas may all aim to improve the quality of life, in practice, in their influence on company and PSRE strategies, they frequently counteract one another and so attenuate the desired effect.

Market-related factors also influence decision making in industry and PSREs, the most important for this project being the policies of food processors and distributors and also public attitudes and opinion, which often set more demanding standards than those of national governments and the EU.

The PITA project (see Project Structure) is developing an integrated analysis of policies and market-related factors relevant to the agrochemical, biotechnology and seeds sectors. The core of the project is an investigation of the impact of these factors on the strategies and decision making of companies and PSREs and the downstream implications of these decisions on employment, international competitiveness and environmental benefits. The final outcome will be feedback of our conclusions to policy makers and company managers.

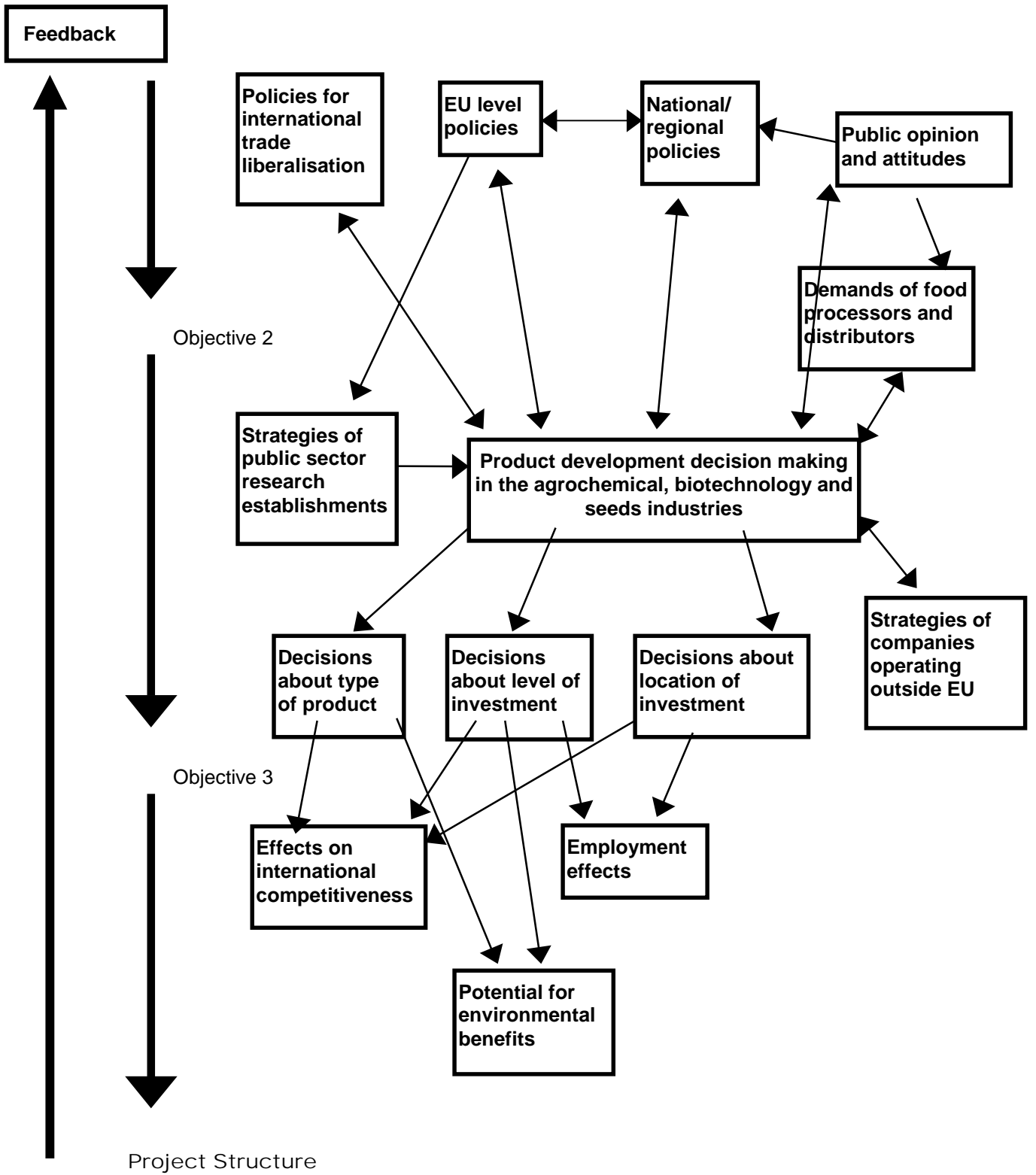
The range of policies and other influences studied includes:

- policies to stimulate innovation in the agrochemical, biotechnology and seeds industries;
- purchasing policies of food processors and distributors;
- policies for international trade liberalisation;
- policies for the regulation of industry and farming (for environmental protection and public health and safety, particularly for pesticides and biotechnology);
- agricultural and farming support policies, particularly for crop production;
- policies to promote environmental sustainability and wildlife biodiversity in arable farming areas;
- public opinion and attitudes.

The overall aim of the project is to contribute to the development of sustainable industrial and farming systems and an improved quality of life by encouraging the development and uptake of 'cleaner' technology for intensive agriculture. Its objectives are:

- to develop an integrated analysis of policies and market-related factors relevant to technological innovation in the agrochemical, biotechnology and seeds sectors, to study their interactions and to develop hypotheses about their impact on strategic decision making in industry and PSREs.
- to study the influence of policies and market-related factors on innovation strategies in the agrochemical, biotechnology and seeds industries and PSREs, and their impact on decisions about product development, levels of investment and location of investment.
- to study the outcomes of the industry decisions investigated under objective 2, in their effects on employment, on international competitiveness and on their potential to deliver environmental benefits.

Objective 1



Contents

1. INTRODUCTION	5
2. OVERVIEW	5
2.1 POLICY TRENDS IN PUBLIC SECTOR FUNDING	5
2.2 SOURCES OF PUBLIC FUNDING	6
2.3 PSREs IN CROP-RELATED RESEARCH	10
2.4 LINKS BETWEEN THE PUBLIC AND PRIVATE SECTOR	10
3. CASE STUDIES	12
3.1 THE JOHN INNES CENTRE	12
3.2 THE INSTITUTE OF ARABLE CROPS RESEARCH	16
3.3 HORTICULTURE RESEARCH INTERNATIONAL	19
3.4 SCOTTISH CROP RESEARCH INSTITUTE	21
4. CONCLUSIONS	22
REFERENCES	25

1. Introduction

This report examines the relation between public and private sector research on agricultural chemicals, biotechnology and seeds, from the perspective of public sector research establishments (PSREs) in the UK. PSREs are those establishments whose research is predominantly funded by government, including research institutes, universities and national laboratories.

It was assumed at the outset of the research that PSREs might influence innovation in the private sector in the following five ways:

- By providing basic research ideas
- By transmitting technical knowledge
- By developing researchers' competence
- By supporting regulatory controls (e.g. by conducting analyses and risk assessment research)
- By acting as a watchdog on behalf of the public.

The research drew from the theoretical literature, annual reports of the PSREs and interviews with senior people in the key PSREs. The interviews were conducted in an open-ended manner, around the topics of decisions about research strategy and interactions with industry.

The report has the following structure. Section 2 provides an overview of public sector research, covering trends in funding, sources of funding and the main PSREs involved in PITA-related agricultural research, and literature on public-private sector linkages. Section 3 provides case studies of four of the main PSREs. Section 4 discusses the conclusions.

2. Overview

2.1 Policy trends in public sector funding

PSREs linked to agriculture have faced considerable changes since the early 1980s. These were triggered by growing criticism of the Common Agricultural Policy, in terms of the cost of surplus production to the taxpayer and the impact of intensive agricultural production on the environment. Between 1994 and 1997, the conservative government conducted an extensive review of the potential for privatisation and rationalisation of public sector research (HRI, 1999: 20).

Research priorities were changed. Public funding for research to increase productivity was drastically cut. Funding for 'near market' research was redirected towards basic research of relevance to the whole food sector, not just agriculture, and towards addressing public concerns about food safety and the environment (Thirtle *et al.*, 1997).

Some establishments were closed, amalgamated or privatised, and the public sector was expected to become less dependent than before on government funding. For example, the Glasshouse Crops Research Institute was sold for property development in the 1980s and some of its work transferred to Horticulture Research International. The Plant Breeding Institute, widely known for its work on cereals, was sold in the late 1980s to Unilever, who subsequently sold it on to Monsanto. In 1997, most of the work of the Agricultural Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food was privatised.

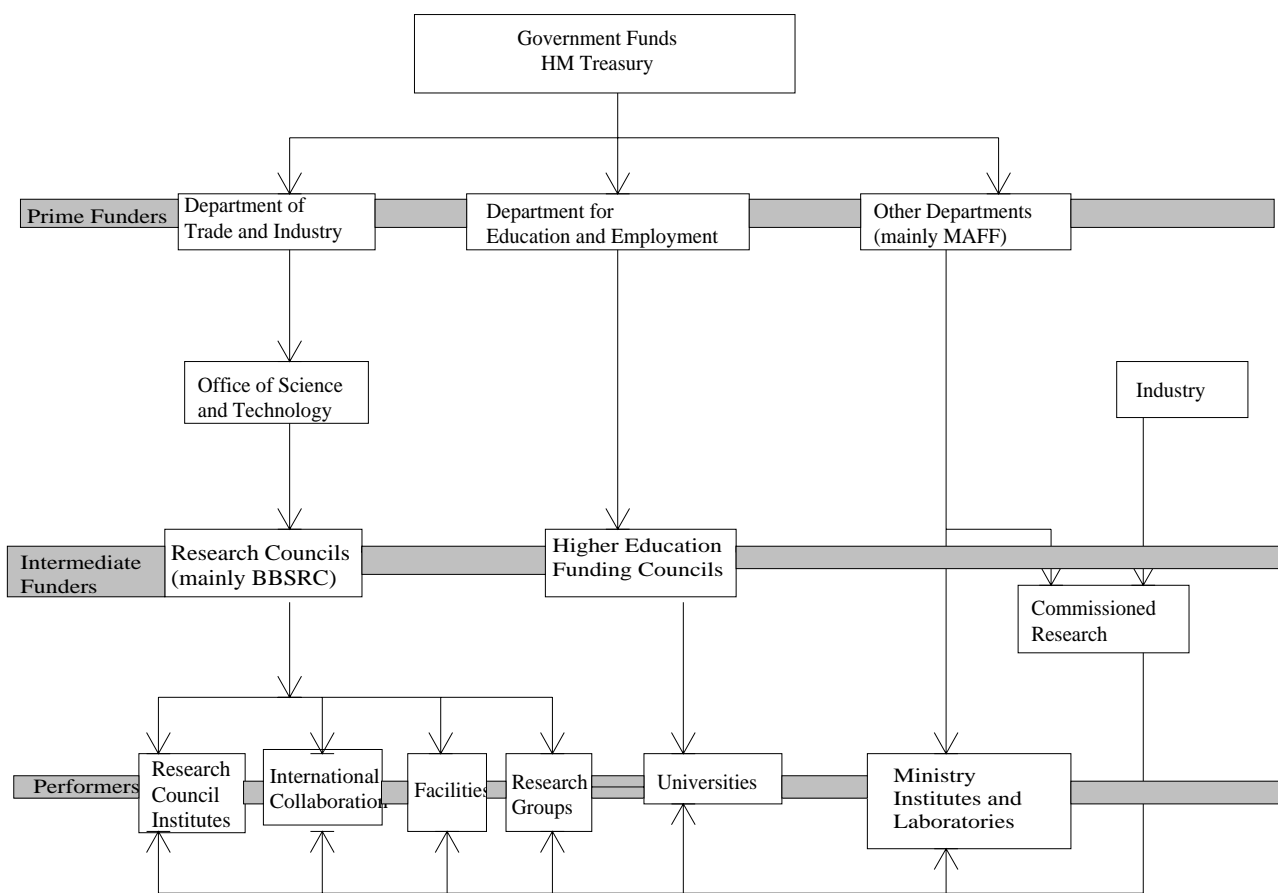
The funding process became more open and competitive, with a wide range of institutions, both public and private, being invited to bid for funds for specific research topics (Thirtle *et al.*, 1997). The public sector was encouraged to form links with industry, both to help

compensate for the decline in government funding for research, and to stimulate more rapid commercial uptake of research ideas.

With the change to a Labour Government in 1997, pressures on the PSREs to commercialise their research have increased rather than decreased. A report on this subject commissioned by the Treasury recommended that the Government should seek 'to ensure that leadership in the PSREs is committed to drive commercialisation as an explicit part of their mission'. This objective 'should be embodied in the job description and personal objectives of the PSRE chief executive and be seen as his or her personal responsibility. It should be cascaded through the personal objectives of senior management and scientific staff' (HM Treasury, 1999). The report, which was based on research on more than 40 PSREs, singled out the biosciences as a research area in which there is a strong industry demand or 'pull'. This is because the industry is characterised by large successful companies with the resources to seek out and exploit PSRE research, and because biomolecular science offers revolutionary, rather than incremental, advances in products and processes.

2.2 Sources of public funding

Public funding for crop-related research comes from research councils, central government departments and regional governments. An additional source of funding, which straddles the boundary between public and private sector, is that from the agricultural levy boards. The structure of crop-related research funding in the UK is shown in simplified form in Figure 1.



Source: Adapted from Martin, 1998: 10

Figure 1 Simplified structure of crop-related research funding in the UK

Of the research councils, the Biotechnology and Biological Sciences Research Council (BBSRC) is the most significant (it spent 270 million ecu on research in 1997/98 – Martin, 1998: 3). It was created in 1994 from a merger between the Agricultural and Food Research Council and related parts of the Science and Engineering Research Council, because of a perceived lack of co-ordination between research councils.

Other research councils that fund a small number of research projects relating to crops and biotechnology are the Engineering and Physical Sciences Research Council (EPSRC), the Natural Environment Research Council (NERC) and the Social and Economic Research Council (SERC).

Of the central government departments that fund crop-related research, the most significant are the Ministry of Agriculture, Fisheries and Food (MAFF) and the Department of Trade and Industry (DTI). Small amounts of funding are provided by the Department of the Environment, Transport and the Regions (DETR) and the Department for International Development (DfID). MAFF has historically been the main government department promoting the UK agriculture and food industries. The DTI supports collaboration between UK industry and the research base through schemes such as LINK, EUREKA, SMART, the Teaching Company Scheme and ROPAs (Realising our Potential Awards). The DETR is the competent authority for the risk assessment of genetically-modified crops and funds risk assessment research to support this role. DfID funds research aimed at benefiting developing countries, often within the country concerned.

ANNEX E7

Funding for agricultural research in Scotland is devolved to the Scottish Executive Rural Affairs Department (SERAD, formerly called the Scottish Office Agriculture, Environment and Fisheries Department, SOAEFD). In Northern Ireland, it is devolved to the Department of Agriculture for Northern Ireland (DANI).

Some funding for crop research in the public sector is provided by agricultural levy boards, in particular the Home Grown Cereals Authority (HGCA) and the British Sugar Corporation (BSC, part of Associated British Foods). These statutory bodies are legally empowered to impose mandatory levies on agricultural output, mainly to support 'near market' research for the industries they serve. The HGCA provides significant funding to the National Institute of Agricultural Botany, which conducts varietal trials and produces lists of recommended seeds. The BSC is a major source of funding for Broom's Barn Experimental Station, which conducts research on sugar beet.

Overall, BBSRC and MAFF are the main sources of funding for crop research. Each provides core funding for particular research institutes, as well as offering funding that is open to competitive bids. For example, BBSRC directly funds research in eight research institutes, including the John Innes Centre and the Institute of Arable Crops Research (see Table 1). MAFF's research institutes include Horticulture Research International.

The research councils, such as BBSRC, mainly fund basic and strategic research. Research councils have been encouraged to make their commitment to 'wealth creation and the quality of life' more explicit and to develop closer links with the communities that use their research, such as industry (UK Government, 1993). Much greater emphasis has been given to the involvement of industry in the design and management of research programmes.

Central and regional government departments, such as MAFF, focus on applied research to address specific policy problems. Since 1997, when the government changed from conservative to labour, changes in government priorities have led MAFF to place increased emphasis on research into food quality and safety, diet and health, protection of the environment and lower input crop production systems, including organic agriculture. However, MAFF's research budget, which used to be one of the largest among government departments, has been severely cut (by 10% since 1997, House of Common's Science and Technology Committee, 2000). The BBSRC has come under increasing pressure to help make up the shortfall, but says it lacks the flexibility to support an area of work when MAFF funding is withdrawn (Farrar, 2000).

Table 1 Principal agriculturally-related research institutes in the UK

MAFF's research institutes
Directorate of Fisheries Research
Central Science Laboratory
Agricultural Development and Advisory Service
Horticulture Research International
BBSRC-sponsored institutes
Babraham Institute
Institute of Arable Crops Research
Institute of Animal Health
Institute of Food Research
Institute of Grasslands and Environmental Research
John Innes Centre
Roslin Institute
Silsoe Research Institute
Scottish agricultural and biological research institutes
Scottish Crop Research Institute
Hannah Research Institute
Macaulay Land Use Research Institute
Moredun Research Institute
Rowett Research Institute

There is little direct funding of industry research by government except through schemes that promote co-operation between the public and private sector such as the LINK programme, which is run by the Department of Trade and Industry and supports long-term, 'enabling' and 'generic' research in areas of strategic importance to the national economy (Martin, 1998: 9). Other government schemes that encourage public-private sector cooperation include the Teaching Company Scheme (which involves joint supervision by academics and company managers of young graduates working in companies), awards for PhD research jointly supervised by an academic department and a company, and ROPAs (Realising our Potential Awards) to academic researchers who have received significant industrial research contracts.

Although the direct funding of industry research by government is limited, government supports industry indirectly by encouraging industry involvement in guiding public sector research priorities, through industry representation on management boards and research councils, and through jointly-funded projects. In addition, the research councils have had to take account of the research priorities established by the Office of Science and Technology's Foresight Programme, whose panels include industry people.

Martin (1998: 57-58), referring specifically to biotechnology, includes the following as distinctive aspects of the UK's funding system for research in the public sector:

- (i.) the system is pluralistic but highly concentrated (there are several different funding organisations but BBSRC is by far the most significant one)
- (ii.) the funding is science oriented (most research council funding goes to basic and strategic, rather than applied, research; a strong science base is seen as the main way of encouraging technological innovation)

- (iii.) a significant proportion of the funding for agriculturally-related research is directed (by comparison with funding for medical research, which for the most part is non-directed); priorities are to a large extent set by the funding organisations, especially for the research institutes; however, for universities, funding is not usually directed
- (iv.) there is a high level of involvement of the private sector in management boards, councils and committees of the funding organisations
- (v.) considerable emphasis is placed on the commercial exploitation of research.

2.3 PSREs in crop-related research

In the UK, publicly-funded research relating to agriculture occurs mainly in specialist research institutes and, to a much lesser extent, in universities. The principal research institutes working on crops, and their sources of funding, are shown in Table 2.

Table 2 Principal research institutes working on crops, and their sources of funding, 1998-99

	Total income (£ million)	Funding as % of total					
		BBSR C-csg	BBSRC-ca	MAFF/ SOAEFD	Industry	EU	Other
IACR	26	30	11	26	15	10	8
JIC	21.5	45	11	6	5	11	22
HRI	30.4	13		61	na	na	27
SCRI	12.4	na	na	68	na	na	32

IACR = Institute of Arable Crops Research; JIC = John Innes Centre; HRI = Horticulture Research International; SCRI = Scottish Crop Research Institute; BBSRC = Biotechnology and Biological Sciences Research Council; csg = competitive strategic grant; ca = competitive award; MAFF = Ministry of Agriculture, Fisheries and Food ; SOAEFD = The Scottish Office Agriculture, Environment and Fisheries Department; na = breakdown not available.

Sources: IACR, <http://www.iacr.bbsrc.ac.uk/iacr/funding.html> (accessed 19/02/00); JIC, JIC (1999) Governors' Report and Financial Statements, 31 March, p. 13 (excludes £ 3 million income of the Sainsbury Laboratory); HRI, Finance Department Statement of Financial Activities, 31 March 1999 (personal communication 04/07/00); SCRI, Annual Report 1998/99, p. 204.

The universities that have received the most funding for non-medical biological sciences from the BBSRC and MAFF are Cambridge, Edinburgh, Oxford, University College London, Nottingham, Birmingham and Sheffield (Martin,1998, p. 62).

2.4 Links between the public and private sector

In an analysis of public-private knowledge flows in agricultural research, Senker and Faulkner (1999) note that at the beginning of the twentieth century there was considerable interaction between universities and industries involved in science and engineering, but that this interaction declined when industries established their own research laboratories. Now there is a revival of public-private sector interactions, which Senker and Faulkner consider is due to a number of factors:

- (i.) the large number of scientifically literate graduates, who continue to develop their skills when they leave university for industry and are able to understand and assess the value of the work university researchers are doing
- (ii.) intense competition among companies in technology-based industries, so that they are continually searching for new ideas and shorter development cycles

ANNEX E7

- (iii.) the tendency for innovation to arise at the interface between disciplines, so being more likely to occur in universities than in companies whose employees are from a limited set of disciplines
- (iv.) reduced government funding for research, which forces public sector scientists to seek private sector funding
- (v.) the poor economic performance of the country in the late 1970s and early 1980s, which led governments to promote 'technology transfer'.

Senker and Faulkner say that, for the private sector, innovative research in the public sector provides a source of 'leading edge' and underpinning knowledge, new experimental techniques and instrumentation, and expert interpretation of results. However, companies need internal expertise in order to understand and use public sector research. Cohen and Levinthal (1990, cited in McMillan et al., 2000) refer to this as a company's 'absorptive capacity'.

According to Senker and Faulkner, factors encouraging public-private sector interaction stem from the technology as well as from the public and private sectors. Technology-related factors include the character of the technology and the age and dynamism of the research field. Interaction is likely to be greater when the technology has application as a research tool, as genetic engineering does in biotechnology. Links with the public sector are more likely in new fields or in fields where the industry has no existing capability, so links tend to be intense in biotechnology because new knowledge and techniques are emerging all the time. Public-sector related factors include the availability of expertise in the public sector and the public policy context. In the case of biotechnology, the underpinning discipline of molecular biology developed entirely in the public sector and is comparatively well funded. Public policy supports public-private sector collaboration. Private-sector related factors include the size of the company, its existing knowledge base, and its propensity to network. Large companies have budgets that allow them to fund formal linkages. They tend to use these links for speculative and exploratory research for which they lack in-house expertise. They may second a member of staff to work alongside an academic researcher, or recruit an academic researcher to collaborate on a project. They may form links to gain access to expensive instrumentation and to have the results interpreted by experts. Some companies have a greater propensity to form links than others; they are more 'extrovert' and encourage their staff to network informally by attending conferences and seminars.

Barnes (1999) investigated reasons for public-private sector links in the agro-food industries from the perspective of the private sector. His findings support those of Senker and Faulkner in that the main reasons given for the links were to gain in-depth expertise and to compensate for a lack of company resources. A third reason was that the partners in the link had similar research programmes. Factors that discouraged links were company concerns over copyright and confidentiality, the length of time needed to negotiate contracts, research programmes too broad for a company's needs, and limited awareness of what the public sector might offer.

In his conclusions, Barnes raised a number of concerns about the impact of current government policies relating to public-sector research. One was that the damaging effect of cutbacks on a loss of public-sector expertise, valued by industry, might not be felt for some time because of the long-time lag (16 years and upwards) between expenditure and final output. Another was that the encouragement of industry links might discourage academic freedom, publication of results, and multi-disciplinary research.

Other authors have voiced some concerns about the increasing dependence of the public sector on private sector funding. For example, Senker and Faulkner (1999, p. 18-19) note: 'Current Government policy to privatise many MAFF research laboratories and extension services, as well as encouraging public sector researchers to seek contracts from industry makes it unclear where independent knowledge about the governance of technology now resides'. The numerous formal research links between the private and public research sectors 'raise doubts about the capability of PSR [public sector researchers] to act as independent advisers to Government on topics such as the regulation of genetically modified

organisms'. In 1999, Friends of the Earth campaigned on just such an issue, pointing out that several members of the government's Advisory Committee on Releases to the Environment (ACRE) and Advisory Committee on Novel Foods and Processes had received funding from industry. As a result, all government committees involved in biotechnology now have to publish details of any commercial and other interests of their members (DETR, 1999, paragraph 26).

Similar concerns have been voiced, albeit more guardedly, by scientists within the public sector. For example, a report on research at the Scottish Crop Research Institute into gene flow from GM crops mentions 'the impartiality of the science and the scientists that are carrying out ecological risk assessment' as a significant factor in the public debate. It comments: 'while science must work with industry, it has to retain a degree of independence through public funding. Otherwise people will not believe its findings on these issues' (SCRI, 1999: 54).

3. Case Studies

This section describes four UK PSREs of particular relevance to PITA: the John Innes Centre (JIC), the Institute of Arable Crops Research (IACR), Horticulture Research International (HRI) and the Scottish Crop Research Institute (SCRI). The information is based on interviews at JIC and IACR, supplemented by annual reports and institutional websites.

3.1 The John Innes Centre

3.1.1 *Background*

The John Innes Horticultural Institution was founded in 1910 by John Innes, a City of London merchant. His bequest is administered by the Trustees of the John Innes Foundation. The Institution was the UK's first plant breeding and research centre. William Batesman, the first director of the institution, was a pioneer of the science of genetics and was the first person to coin the word 'genetics', in a letter in 1905 (JIC website, accessed July 2000). In the mid-1930s, the appointment of a Director with an interest in soils and agriculture led to the formulation of 'John Innes Composts', which are still widely used in the UK by horticulturists and gardeners.

In 1966-67 the Institute moved from Merton to its present site in Norwich and formed close links with the nearby University of East Anglia (JIC website, accessed July 2000). In 1990, the non-privatised part of the Plant Breeding Institute in Cambridge moved onto the Norwich site as the Cambridge Laboratory. The John Innes Centre was formed in 1994 by the merger of the John Innes Institute, the Cambridge Laboratory and the Nitrogen Fixation Laboratory of Sussex University. The John Innes Centre leases its land, building and glasshouses from the Foundation for a nominal rent. The Foundation sets certain conditions on overall policy, for example, no animal research and in particular, no experiments on live animals. The Foundation also funds studentships. The John Innes Centre is a company limited by guarantee and a registered charity (JIC, undated: 8). It views itself (and is viewed by others) as a 'leading international centre of excellence' in plant and microbial research (JIC, undated: 7).

JIC's mission is to 'contribute to enhancing scientific knowledge, the quality of life and economic well-being' by conducting high quality research and training, disseminating knowledge and technology to meet the needs of users and beneficiaries, and providing advice and promoting public understanding (JIC, undated: 4). Its main users are seen as the worldwide scientific community in agriculture, bioprocessing, food, healthcare, pharmaceutical, chemical and other biotechnological industries, as well as governments, the EU and the general public (JIC, undated: 9).

JIC is 'scientifically, physically and administratively linked' with the Sainsbury Laboratory, which was established as a joint venture between the Gatsby Charitable Foundation, the

University of East Anglia, the BBSRC and the John Innes Foundation (JIC, undated: 8). Now meetings are underway between the John Innes Centre and other institutions on the Norwich Science Park site – the Food Research Institute, the University of East Anglia, and the new regional hospital – to discuss the possibility of collaborative research on proteonomics (M. Gale, Acting Director, interview, 30/11/99).

3.1.2 Staff

JIC has approximately 850 scientists, support staff, visiting workers and students (Finance Department, personal communication 28/6/2000). There are about 155 permanent scientific staff members at JIC, and 25 core scientific staff on five-year contracts at the Sainsbury Laboratory (JIC, 1999: 116). More transient staff include about 200 research students on three-year grants, about 150 staff on contracts of one to three years, and visiting scientists who join the Centre for periods of a few weeks to a year (JIC, undated: 29). There is therefore a high turnover of scientists, which helps to maintain a 'vibrant research programme' but means that much effort has to go into attracting and training the 'transient' contributors and maintaining the right complement of scientists.

The incoming Director, Chris Lamb (appointed in October 1999), has floated the idea that new senior people might be appointed just for five years, with only a proportion selected to stay on. This is likened to the Harvard system, where 90% of people are expected to move on at the end of their contract (R. Thornley, interview, 30/11/99).

The sharing of information among staff within the JIC is seen as important for stimulating ideas, for example informally through the tea room and more formally through departmental meetings, reports back from conferences, and the circulation of abstracts. A 'skills base index' is being compiled, including for example language skills, to encourage networking among people with the same or a complementary index. *'There are special grants of £6k to support interactions across departments, for example to employ a student to do a particular piece of research. Visitors are encouraged, but there is a 'head tax' if they stay more than three weeks, for example of £7500 a year for a post-doc researcher'* (R. Thorneley, interview, 30/11/99). The research they do can provide the basis for a grant application: *'the results can be used as leverage to get external funding'*.

3.1.3 Funding

The combined income of JIC and the Sainsbury Laboratory in 1998/1999 was almost £25M. JIC's principal sponsor is the BBSRC (see Table 1). BBSRC funding takes the form of a Competitive Strategic Grant (core funding), supplemented by three-year grants for specific projects. The strategic grant is set following a four-yearly Institute Assessment Exercise (IAE) conducted by a Visiting Group from the BBSRC. After the IAE in 1997, the Visiting Group concluded that JIC is 'without doubt, one of the world's leading centres of expertise in plant and microbial science' (JIC, 1999: 116). In recognition of this, the BBSRC awarded JIC a one-off grant of £1 million to build a new gene function laboratory, which will be used to strengthen links with industrial collaborators.

Other funding comes from government departments, in particular MAFF, from charities including the Gatsby Foundation (funded by the Sainsbury family), and from commercial companies (see Table 2). The aim is to increase industry funding to 15% of total income. In 1998, it increased from 2% to 9% as the result of two large contracts, one with Zeneca, who plan to invest £50 million over ten years in a joint research programme, and the other with Dupont, who will put in \$1 million over five years. Both contracts are for the development of improved varieties of wheat: *'Here we have the largest concentrations of experts in wheat and wheat biotechnology so both [companies] chose us when it became clear the next big bonanza would be European wheat. ... Wheat has the highest yields and biggest acreages. Wheat is the biggest crop in the world – 500 million tonnes.'* (M. Gale, interview, 30/11/99). As part of the project, a new laboratory is being built on the JIC site for 30 Zeneca scientists (Zeneca, 1998). The fact that Europe has a Plant Breeders' Rights treaty in place is seen as an added incentive to industry investment.

The JIC management *'tries to create an environment to encourage interaction with industry'* (M. Gale, interview, 30/11/99). For example, JIC staff do consultancies for industry. Company links *'serve as a leverage to get funds from DTI'*, for example through the Link scheme. The drivers for interaction with industry, according to one of JIC's senior scientists (Professor R. Thorneley), are *'to obtain funding, and as part of the RAE [Research Assessment Exercise, which has] industrial interactions as one of the [evaluation] categories'*. Some misgivings were expressed about the possible impact on research of an over-emphasis on industry links: *'The industry emphasis in Framework Programme Five causes concern. It's OK so long as it doesn't distort our research programme, e.g. you've almost got to promise a product in five years'* (R. Thorneley, interview, 30/11/99).

Professor Thorneley gave three examples of how industry links come about, stressing the importance of personal contacts. In the first example, Zeneca provided funding for research into the enzyme chorismate synthetase for its potential as an anti-microbial or herbicide: *'That link came about through an ex-student from the Nitrogen Fixation Laboratory. He remembered the techniques and expertise. Plus I'm in an EC network'* (R. Thorneley, interview, 30/11/99). In the second example, similar networking led to Unilever funding for a postdoctoral researcher to work on plant peroxidases involved in the processing of tea: *'I co-ordinate two EC networks on peroxidases. I was at a scientific meeting to which Unilever sent a rep. They wanted to be involved in the network. ... There were some problems [about allowing Unilever to be part of the network] because one member had links with another company. Out of that network we received 500k ecu under the Mobility programme of Framework III. Under Framework IV, the network grew from seven labs to ten, with 1.5 million ecu. Unilever is associated with it – it supplies the bulk tea leaves. It's useful because of the importance of industrial links under the Framework programme'* (R. Thorneley, interview, 30/11/99).

The third example of an industry link, establishing a new line of research into proteonomics, came about because Peter Lillford of Unilever is a member of the JIC governing council. Roger Thorneley explained how both industry and the JIC benefit from the resulting collaboration: *'To get funding for capital equipment, £400-500k, we bid to government but we have to find matching funds, i.e. from overheads on independent or industrial grants. I talked to Unilever. They're at the stage of thinking they want to do proteonomics. Unilever and Zeneca have agreed. They are also funding five-year post-docs to operate the machines. So that's £300k for equipment and the post-docs. They're pleased because they have access to equipment and training. We provide mass spectrometry skills and training. We're both on a steep learning curve. Unilever can run samples or learn to do the process themselves.'*

In 1994, the JIC with the support of the Gatsby Charitable Foundation set up a company, John Innes Centre Innovations Ltd, later renamed Plant Biosciences Ltd. The aim was to exploit JIC's intellectual property more effectively and manage its relations with industry more efficiently (JIC, undated: 24: M. Gale, interview, 30/11/99): *'Before, the normal situation was that if a company gave some money for research, you handed over all the intellectual property to the company, even if the research wasn't fully funded [by the company]. So in 1994 it was decided that no intellectual property should ever leave the Centre again. It was unpopular with UK companies, e.g. Zeneca, but US companies were used to it, e.g. Dupont, Pioneer were not the least bit phased, Monsanto even. We lost some grants but it was a blip. Now it's the norm in the UK.'* Another researcher confirmed that this system generally worked well but that in practice it was a little more flexible than had been suggested: *'[There were] some difficulties with part of Unilever, but we negotiate rather than lose [a contract] because we can't agree on IPR [intellectual property rights]. Science comes first, then profit'* (R. Thorneley, interview, 30/11/99).

In return for research funding, companies get a licence to use any resulting intellectual property but with certain restrictions: *'Depending on how close it is to full funding we may give the company a sole exclusive licence to the intellectual property or, if it's less than full funding, a non-exclusive licence. [But there are] two key things. (1) The exclusive licence is [only] for those crops the company specialises in (e.g. soyabean in the US, wheat, barley and rice all over the world, but not for e.g. cassava and pearl millet) – so we could take the intellectual property and use it on behalf of developing countries. (2) All the licences have a*

performance clause. They can't just stick it in the drawer [and forget it]. If they don't prosecute it, it reverts to JIC (M. Gale, interview, 30/11/99).

Most of the patents are for plant and microbial genes: *'We're strong in flowering, plant development, product manipulation – enzymes that manipulate starch, oils – some germplasm for breeders' use, some techniques'* (M. Gale, interview, 30/11/99). Patents that do not live up to expectations are not retained: *'The portfolio is rigorously maintained, i.e. draconian cutting of things – patents become more expensive after five years, which is a problem if they're not bringing in royalties'*. In 1997, a two-year award under the DTI's 'Biotechnology Means Business' initiative allowed the company to offer a service managing patents on behalf of other organisations (JIC, 1999: 10): *'We have 40-50 [patents] on our books now. Not all of them are from here. Some are from other universities, or even the US, because we've developed an expertise on patents'* (M. Gale, interview, 30/11/99).

Some of the royalties from the company are channelled back to the Centre to fund further research. This provides an additional incentive for researchers to develop appropriable products: *'It [the setting up of the company] resulted in a sea change in the way we think about our research – reward is now a driver, though not the only one'* (M. Gale, interview, 30/11/99).

3.1.4 Research strategy

Research at the John Innes Centre is organised under five main themes:

1. How genes are organised and function in plant, microbial and viral genomes
2. How biological structures perform specialised functions
3. How plants and microbes grow and develop
4. How valuable products are made and accumulate in plants and microbes
5. How plants and microbes respond to changes in their environment (JIC, 1999: 8-10).

These research themes have been formulated in the context of the priorities of the Centre's principal sponsors, especially the BBSRC, as well as those identified by UK Technology Foresight, and those apparent in worldwide research in biological sciences and biotechnology (JIC, 1999: 8). In describing his objectives as acting director, Professor Gale confirmed the importance of the objectives set by BBSRC and added the specific goal set in 1998 of increasing industrial funding from 2% to 15%. He mentioned the influence of the previous government's White Paper on Wealth Creation, published in 1992: *'The other top down driver that we take very seriously is the 1992 paper on wealth creation, which really put a very different slant on our work – [it recommended] mechanisms to move discoveries to the consumer more quickly'* (M. Gale, interview, 30/11/99).

Within the framework set by these priorities, decision making on research appears to be a democratic process: *'We're a democratic place'* (M. Gale, interview, 30/11/99) and *'It's bottom up'* (R. Thorneley, interview, 30/11/99). Project leaders are key: *'They are often recruited young. They may be recruited to work on a particular area, [but within that] they do what they want'* (R. Thorneley, interview, 30/11/99).

A Centre Scientific Strategy Committee meets once a month *'to talk about where we want to be in 5-10 years' time, what facilities and appointments we'll need. ... We look at the key areas of science where there are opportunities, taking the competition into account and industry. E.g. the GM argument is central now ... [what should we be doing] while industry is keeping its head below the parapet?* (M. Gale, interview, 30/11/99).

The committee commissions 'horizontal reviews' on the key areas they identify. These reviews usually involve a senior scientist, who may organise a small committee or hold a one-day conference or workshop with internal, and sometimes external, people. If the conclusion is that research in that area should be developed, funding for new posts and equipment may be released: *'Usually the outcome is they say "it's a very important area, we need five new scientists". Sometimes they get one. We reckon it costs a quarter of a million*

pounds to employ a new project leader, with equipment, technicians etc.' (M. Gale, interview, 30/11/99). Professor Thorneley, a project leader and a member of the Centre Strategic Committee, explained that heads of departments and project leaders can make a case for new research to the committee, although the Director is ultimately responsible for decisions involving new appointments.

3.1.5 *Environmental issues*

The Centre stresses its concern for the environment: 'The company is concerned with the conservation and protection of the environment in the broadest sense and recognises that certain resources are finite and must be used responsibly' (JIC website, www.iacr.bbsrc.ac.uk, accessed July 2000). It aims to work with others on environmental quality standards, to ensure its activities do not harm the environment, to assess in advance the potential environmental effects of new developments and new research and to have particular regard for the preservation of wildlife habitats.

The interviews gave little indication that environmental issues were considered a priority. This may be because the main focus of the interviews was on industry links, but there is little mention of environmental issues in the Centre's literature either. There was a suggestion that the strong emphasis on research of interest to industry was responsible for some lines of research with environmental relevance being discontinued. For example, after the most recent BBSRC visiting committee review, the focus of the work of the former Nitrogen Fixation Laboratory was switched from the enzymes involved in nitrogen fixation to other related work on enzymes relevant to herbicide and antibiotic tolerance. The project leader explained this was because there was little industrial investment in nitrogen fixation because nitrogen fertilizer manufacture is efficient and cheap, *'but in 20 or 30 years time it [the nitrogen fixation work] may be more important ... [to alleviate environmental problems such as] greenhouse gas formation and nitrate in water supplies'* (R. Thorneley, interview, 30/11/99).

3.2 The Institute of Arable Crops Research

3.2.1 *Background*

The Institute of Arable Crops Research (IACR) is a loose consortium of two publicly-funded research organisations (Rothamsted Experimental Station and Long Ashton Research Station). A third organisation, Broom's Barn, is formally part of Rothamsted but is funded by a levy on sugar beet growers and British Sugar. Research activities across all three sites are co-ordinated within a single management structure.

The Rothamsted site is thought to be the oldest agricultural research station in the world, dating back to 1843 (IACR website, www.iacr.bbsrc.ac.uk/res/taboures.html, accessed 20/06/2000). The scientific partnership between the two founders, Lawes (the owner of the Rothamsted Estate) and Gilbert (a chemist he appointed as his scientific collaborator), laid the foundations of modern scientific agriculture and established the principles of crop nutrition. Some of the long-term field experiments on inorganic and organic fertilisers that were begun in 1843 continue to this day. Rothamsted is also known as the birthplace of modern statistical theory.

The Lawes Agricultural Trust provides Rothamsted with land and accommodation for a nominal rent, playing a similar role to that of the John Innes Foundation at JIC. The terms of the Trust are research for the benefit of agriculture, in a broad sense, so it exercises no real control over strategy (I. Crute, interview 11/01/2000). It provides modest sums of money for research and funds the maintenance of the long-term research sites.

IACR's mission is 'to be a leading provider of high quality research relevant to plant-based agriculture with the objective of achieving improvements in rural and agricultural economies that are financially, environmentally and socially sustainable' (IACR website, accessed 19/02/2000). Its scope is therefore much broader than JIC's mission and it makes explicit reference to IACR's environmental and social responsibilities. IACR includes among its client

ANNEX E7

base: government departments (MAFF, Department for the Environment, Department of Trade and Industry), arable farmers, crop consultants and processors, biotechnology companies, and more generally, society and NGOs (IACR website, accessed 20/06/2000).

3.2.2 Staff

The Institute employs about 720 scientific and support staff, of which 220 are at Long Ashton, almost 40 at Brooms Barn, and the rest at Rothamsted (IACR website; I. Crute, Director, interview 11/01/2000). In addition, there are about 160 visiting workers/students across the three sites.

3.2.3 Funding

IACR's total income in 1998/99 was over £26M (see Table 2). Like JIC, IACR's principal sponsor is the BBSRC, which in 1998/99 provided about 30% of that total as Strategic Grant (core funding) and a further 11% as grants for specific projects awarded through open competition. Compared with JIC, IACR receives less support from BBSRC but more from MAFF and industry.

Unlike JIC, IACR no longer has a direct link with BBSRC policy formulation through membership of its director on BBSRC's high level committees: *'there was a conscious distancing from the contractor when BBSRC replaced the old councils'* (I. Crute, interview 11/01/2000). IACR has more informal links with MAFF than with BBSRC *'because BBSRC's external constituency is much wider'*.

Compared with JIC, IACR has well established links with industry: *'Recently JIC has struck two quite important deals with industry, but we've always had good industry links'* (I. Crute, interview 11/01/2000). These links are less dependent on one or two key companies than those at JIC: *'We have business relations with a whole range of industries. We're not just doing it with one player. Dupont is on site. We rent them laboratory space – it evolved out of a common interest in cereals'*.

The recent spate of mergers among multinational companies has created problems for establishing and maintaining public-private sector links, as shown by the following three examples: *'There's such a flux [among companies] at the moment. For example, we set up a consortium in the genomics area. We started off talking to six companies, all of whom wished to contribute money but then with mergers it went down to four. Now there are only two or maybe three of those original companies left. ... There's a company with a major involvement in herbicides looking to develop a joint academic-industry partnership – Rhone-Poulenc. That was established. It took a while to get off the ground but now we're in a situation where it's in the balance because of the merger with Hoechst. ... We had a long-standing link with PBI [the Plant Breeding Institute], but change of ownership changes relations'* (I. Crute and S. James, interview 11/01/2000).

Unlike JIC, IACR has not yet set up a company to exploit its intellectual property: *'We're in the process of putting in place a commercial strategy around computer software (from our statistics/decision support history) and secondary plant products e.g. biocontrol, essential oils, but we don't actually have any companies trading at the moment. We need to find the right format to attract investors.'* (I. Crute, interview 11/01/2000).

3.2.4 Research strategy

IACR aims to provide an integrated approach to crop research, combining knowledge from genetics, biochemistry, cell biology and soil processes at the level of both populations and ecosystems (IACR website, accessed 19/02/2000). *'Our comparative advantage – both a strength and a weakness – is that we cover biological science of relevance to the major arable agricultural crops of northern Europe from very fundamental science at the cell biology level all the way through to the complexities of not just even whole farms but the whole catchment or landscape. In that sense we must be almost unique in the UK'* (I. Crute, interview 11/01/2000).

ANNEX E7

In response to recommendations from the BBSRC's 1997 Visiting Committee, research is now organised under four overarching themes:

1. Inherent plant productivity
2. Environment and nutrients
3. Host-parasite interactions
4. Agricultural systems (IACR website, accessed 19/02/2000).

Within each of these themes there are five or six programmes, formed by a consolidation of projects funded from various sources. The BBSRC's visiting committee recommended a strengthening of research into population biology and dynamics, and mathematical modelling, to take advantage of recent opportunities for new insights provided by advances in computing and genetic marking, for example to study weed and insect population dynamics (I. Crute, interview 11/01/2000).

Research priorities are guided by these themes and programmes, within the context of IACR's overall mission. Programme and project leaders are expected to ensure their research contributes to the goals of these programmes. A research strategy committee, made up of most of the Institute's senior scientists, constantly reviews the programmes to consider whether or not they should be continued and to comment on possible changes of direction.

Since most funding is tied to particular projects, any change tends to be gradual: *'Only 30% of our funding is under our control, so opportunities for radical movement are limited'* (I. Crute, interview 11/01/2000). However, sudden changes in government policy can leave key scientists in a vulnerable position: *'Our front-line researchers have historically been MAFF-funded, policy driven, so changes in policy can leave scientists exposed. So one of the strategies we've put in place is to try to secure all key senior scientists on the back of core BBSRC funding ...to look after scientific expertise and key roles and experts'* (I. Crute, interview 11/01/2000). The idea that scientists might be expected to gain, say, 50% of their salary by competitive bidding for funds was viewed as creating instability.

For the proportion of funding that is under IACR's control, priorities are determined partly by the expected outcomes: *'It's based on what I expect science, or the people, to deliver – the quality and impact of that science in terms of research output as measured by publications in high quality journals, and relevance to our mission ... I'm picking out individuals representative of areas of science which I am convinced are going to deliver against criteria of quality and relevance'* (I. Crute, interview, 11/01/2000).

There is now more emphasis on finding research targets of interest to industry, for example to the biotechnology industry – research that is *'likely to be valued in terms of the products that might come out'*. For this reason, a more strategic approach to plant science research is being discussed, involving goals such as the development of quality and stress tolerance traits. The idea is to consolidate IACR's track record, not to compete in areas in which it has little experience. So the strategy is to look for *'opportunities for scientific publications where we already have a lead and can consolidate that lead. Equally we don't go into areas where we're just competing with commercial concerns if we've got no track record, for example, salinity tolerance. Our strategy isn't necessarily to do with the most important things. It's to do with how well positioned we are'* (S. James, interview, 11/01/2000).

Externally, IACR sees a dichotomy in strategy. There is an emphasis on *'science to produce inventions of interest to biotechnology companies, small and large, that is quite reductionist'* and a simultaneous emphasis on the *'delivery of information and knowledge in relation to the interaction between agriculture and the environment'*. The second is becoming more dominant. This dichotomy is similar to the wealth creation/quality of life dichotomy. *'In the developed world, agriculture is at a crossroads. Should the direction be low input, high land use, for example semi-organic, with support for agriculture much more based on environmental concerns? Or should it be taking some land out of production, with high-tech, highly intensive production (in terms of management at least) on the remaining land?'* (I. Crute, interview 11/01/2000). IACR considers that its research can inform both options: *'The*

science that we do can inform both of those scenarios, ensuring that we understand the optimum use of inputs and the totality of the system. If you understand it, you can manipulate the system for either of these two scenarios' (I. Crute, interview 11/01/2000).

3.2.5 *Environmental issues*

IACR takes into consideration the government's wish for a rural economy that provides a secure supply of affordable, safe, good quality, nutritious food without degrading natural resources or ecosystems. The Institute considers that it leads the world on low input farming and the environment (IACR website, www.iacr.bbsrc.ac.uk, accessed 19/02/2000). It has a strong focus on sustainability in farming systems and environmentally-sound crop production. As a consequence it focuses on being multidisciplinary and attempts to take a holistic approach. Research targets include protecting soils from the impact of heavy metals, reducing agrochemical inputs, and minimising pollution from fertiliser use. It plays a lead role in informing government policy on nitrates (S. James, interview 11/01/2000).

3.3 Horticulture Research International

3.3.1 *Background*

Horticulture Research International (HRI) claims to be 'the single largest team of horticultural research and development scientists in the world' (HRI website, www.hri.ac.uk, accessed 04/07/2000). Its headquarters are at Wellesbourne (the former National Vegetable Research Institute), but it includes five other sites that were managed independently before the rationalisation of public sector horticultural research in 1990: East Malling (fruit research), Wye (hops), Efford, Kirton and Stockbridge. Horticultural research has suffered from the general decline in the horticultural sector that occurred when the UK joined the European Community and the sector was exposed to increased competition, particularly from Spanish horticultural imports.

Unlike JIC and IACR, HRI is sponsored by the Ministry of Agriculture, Fisheries and Food rather than by the BBSRC, although it receives funding from both sources. This has made HRI particularly likely to suffer cuts in funding. A recent newspaper report notes that MAFF has cut commissioned funding to HRI by a third in the past decade and that further cuts of between 2% and 5% annually are likely in the next three years (Robertson, 2000). In addition, BBSRC funding is expected to be cut by £600,000 in the next four years. Significant job losses are likely unless HRI can make up the total expected shortfall in funding of £3 million by expanding its commercial enterprises (postscript: in late 2000, it was announced that 150 posts were to go).

HRI's mission is 'To innovate and communicate for the benefit of producers and consumers of horticultural and other plant-based products' (HRI, 1999). Its main customers are the UK public-sector (e.g. MAFF policy customers), the UK horticultural industry and UK-based retailers and processors (HRI, 1999: 21).

3.3.2 *Staff*

HRI has nearly 800 staff of all categories, of which 411 are at Wellesbourne, 147 at East Malling, 90 at Wye, 58 at Efford, 53 at Stockbridge and 26 at Kirton (1998 figures – HRI, 1999: 106-111). These figures include 51 visiting workers and 74 students, based at Wellesbourne and East Malling.

3.3.3 *Funding*

HRI's total research income in the year ending March 1999 was £30.4 million (Finance Department, personal communication, 04/07/2000). As already mentioned, the main source of funding is MAFF (56%), with BBSRC providing 17%, levy boards (Horticultural Development Council and Apple and Pear Research Council) 12% and all other sources 15% in 1998/99 (HRI, 1999: 104).

HRI is being forced to adopt an aggressive marketing strategy in the face of declining public-sector funding. The five criteria that will guide its research priorities in future include alignment with the market-place, and the potential to create saleable intellectual property, products and services (HRI, 1999: 21). HRI's intellectual property, products and services will be exploited under the registered trademark HortiTech, launched formally in February 1998, with the objective of increasing income from commercial sources threefold between 1998/99 and 2002/03 (HRI, 1999:21). The purpose of HortiTech is 'to generate commercial income by transferring technology to industry and creating a commercial philosophy throughout HRI' (HRI, 1999: 101). Internal 'road-shows' have been held 'to initiate the process of staff education and involvement in the vital development of the commercial business capability within HRI' (HRI, 1999: 16). Information has been collected on prospective intellectual property within all the science departments. Market-led business units have been established for commercial R&D services, seed services, propagation services, diagnostic services, technical information services, commercial crop contracting and EU contracting (HRI website, accessed 04/07/2000).

3.3.4 *Research strategy*

HRI's scientists work on a wide range of horticultural crops, in particular those of international importance, including brassicas, strawberry, tomato, chrysanthemum, potato, onion and other alliums, mushroom, hops, apple and farm woodland species (HRI website, accessed 04/07/2000).

In 1997, HRI was assessed along with the eight BBSRC-sponsored research institutes as part of the BBSRC-led Institute Assessment Exercise. The BBSRC's Visiting Group recommended that HRI research should support the needs of retailers and processors, as well as growers, that HRI researchers should publish more widely, not just in specialist horticultural journals, and that HRI should form strategic alliances with other research institutions in the UK and overseas to exploit complementary skills (HRI, 1999: 14).

As in the case of IACR and JIC, research at HRI is now organised under three or four key themes. For HRI the four main themes are:

- Integrated pest and disease management
- Plants, soils and the environment
- Plant physiology and ecology
- Crop improvement.

Since 1997, 22 research strategy teams have been established across HRI, to encourage project leaders to contribute to research decisions. A research strategy committee monitors and co-ordinates the work of these teams. A scientific advisory committee has been set up, with members from outside HRI, to review progress under each research theme every two years and monitor scientific quality (HRI, 1999: 14).

HRI has had to respond to the changes in MAFF research priorities (mentioned in Section 2.2) that occurred after the change in government in 1997. Since HRI already had a sound science base in crop quality and in input reduction it was able to adapt to this change in emphasis (HRI, 1999: 17).

3.3.5 *Environmental issues*

HRI's corporate plan for the five years 1998-2003 announces that HRI intends to become the prime supplier of 'Research and Development for Sustainable Horticulture World-wide' (HRI, 1999: 20). Two of its four research themes emphasise the development of more sustainable systems, for example by working towards reduced agrochemical use for pest and disease control, and improved use of natural and renewable resources.

3.4 Scottish Crop Research Institute

3.4.1 *Background*

The Scottish Crop Research Institute (SCRI) is located in Dundee. It was established in 1981 by an amalgamation of the Scottish Horticultural Research Institute (founded in 1951) and the Scottish Plant Breeding Station (founded in 1921). In 1987 the Institute also took over managerial responsibility of the Biomathematics and Statistics Scotland (BioSS).

SCRI is one of five Scottish Agricultural and Biological Research Institutes. It adopts a broad multidisciplinary approach to research and claims to be unique within the UK research service in that its skills range from fundamental studies on genetics and physiology to glasshouse and field trials (SCRI, 1999: 3). SCRI is the lead centre in the UK for research on potato, barley, brassicas, beans, soft fruit crops (blackberry, blackcurrant, raspberry and strawberry) and forestry. Although it specialises in the crops that are important in northern Britain, it also conducts research on a wide range of temperate, sub-tropical and tropical crops and tree species including cassava, groundnut, mahogany and coffee (SCRI website, accessed 15/02/2000).

SCRI's mission is 'to sustain excellence and our international reputation for strategic research in crop, plant and related sciences, and to facilitate the application of new knowledge to end-user industries' (SCRI, 1999: 7).

3.4.2 *Staff*

SCRI employs about 400 people. Of these, about 280 are graduate scientists, including around 150 postgraduate short-term contract staff and research students (SCRI website, accessed 15/02/2000). The pay and grading system, and staff and management codes, are administered by the BBSRC (SCRI, 1999: 7).

3.4.3 *Funding*

Over 50% of SCRI's funding comes as grant-in-aid from the Scottish Executive Rural Affairs Department (SERAD, formerly the Scottish Office Agriculture, Environment and Fisheries Department, SOAEFD). In the year ended March 1999, of a total income of £12.4 million, 59% came from SERAD as core funding and a further 9% as flexible funding.

SCRI also derives income from Mylnefield Research Services (MRS). This is the commercial arm of SCRI. It was established in 1989 to 'enhance competitiveness, and to understand and fulfil the needs of industry' (SCRI, 1999: 183). In the financial year 1997/1998 this company had a turnover of £1.79 million, £1.16 million of which was used to fund research projects at SCRI. The income was generated from royalties (6%), analytical services and consultancy (5%), contract research (45%) and collaborative research (44%). The creation of joint ventures and spin-out companies is envisaged in future.

3.4.4 *Research strategy*

SCRI has eight science departments: crop genetics, soft fruit and perennial crops, cell and molecular genetics, cellular and environmental physiology, chemistry, fungal and bacterial plant pathology, virology, and nematology (SCRI website, accessed July 2000). Genetics and enhanced breeding of selected crops, and biotechnology are at the core of all SCRI's research and development programmes (SCRI, 1999: 9).

SCRI's research programmes are peer-reviewed at several levels (SCRI, 1999: 8). The projects that form the core research programme are assessed annually by the Research Education and Advisory Services (REA) unit of SERAD. New projects are appraised by advisers before commissioning. Every four years SERAD commissions BBSRC to appoint a visiting group to review SCRI's work. In 1999, SCRI initiated a major science strategy review to assess research objectives and science management, to address the issues raised by the BBSRC visiting group and SOAEFD's strategy review, and to recommend future research

directions, giving high priority to activities with wealth creating potential and industrial relevance (SCRI, 1999: 8).

3.4.5 *Environmental issues*

SCRI includes among its aims the development of more sustainable and environmentally sensitive methods of crop protection. It links the aim of wealth creation with improving the quality of life and safeguarding the global environment (SCRI, 1999: 7).

Mathematical modelling and DNA fingerprinting are being used to assess the risks of GM crops, for example, to examine how the modified genes from oilseed rape might spread from a GM crop to feral plants and weeds (SCRI, 1999: 50). SCRI, in a consortium with the Institute of Terrestrial Ecology and the Institute of Arable Crops Research, is evaluating the ecological impact of GM crops in government-sponsored and farmer-managed trials.

The use of mixtures of cereal varieties is being explored as one way of reducing the need for pesticides while improving yield and quality (SCRI, 1999: 55).

4. Conclusions

This research began with an assumption that PSREs might influence innovation in the private sector by providing basic research ideas, transmitting technical knowledge, developing researchers' competence, supporting regulatory controls and acting as a watchdog for the public. The results show that the PSREs attach considerable importance to the first three roles, and some importance to the fourth, but there was no evidence of the fifth role. Wealth creation objectives appear to take priority over quality of life ones. Public funding is being used as a lever to obtain industrial funding and to undertake 'pure' research. Public-interest research to safeguard health and the environment is relatively neglected.

The extent of the influence of the PSREs on the private sector can only be judged by consulting the private sector. However, the extent of influence of the private sector on the PSREs, and the influence of government policy in encouraging private sector influence on PSREs, is clear.

The four cases show that industry has a pervasive influence on public-sector research goals. This influence extends far beyond the projects that receive some direct funding from industry. The proportion of funding that each institute receives from industry is at most 15% (IACR) and in other cases is far less. Yet proportionately, industry's influence over the research agenda of the public sector is far greater than this.

For all four institutes, identifying industry-relevant research projects is an important strategy. This strategy is driven by two aspects of government policy that reinforce one another in terms of increasing the influence of industry. One is the pressure to increase the speed at which research in the public sector is transferred to industry so that it can contribute to UK wealth creation. The other is the decline in government funding for agricultural research, which creates pressure on the PSREs to find other sources of income.

Below we examine three aspects of the influence of industry on research in the public sector. The first is the way that influence is exerted. The second is the type of companies involved in links with the public sector. The third is the way in which the need to attract industry funding affects public sector research.

Industry influence on the public sector is exerted in a variety of ways. One way is through industry membership of PSRE-relevant committees, as mentioned by Martin (1998). Examples mentioned in the case studies include the UK Technology Foresight committees (which contribute to BBSRC priorities and thence to institute priorities, Section 3.1.4), and institute governing councils (Section 3.1.3). Another way is through research funding that is conditional on, or made more likely by, industry involvement. Examples in the case studies include the European Union's Framework Programme, the DTI's Link scheme, and grants for capital equipment from Government (Section 3.1.3). A third way is through rewards to, or

evaluation of, researchers on the basis of their work with industry. Examples include the ROPAs (Realising our Potential Awards) and the criterion of industry interactions now used in the Research Assessment Exercise (Section 3.1.3).

The case studies suggest that some sectors of industry are more likely to be involved in links with the public sector than others. The larger international companies have the resources and staff with the scientific knowledge to seek out relevant research in the public sector, for example by attending academic conferences, joining research networks and sitting on committees (Section 3.1.3). In seeking funds to make up the shortfall in government funding, PSREs find it easier to target the small number of large companies in the agri-biotech sector than the more fragmented food processing and agricultural sectors. This has several implications. One is that public sector research may increasingly focus on the concerns of the larger international companies. A second is that any wealth creation generated by the public sector as a result of funding from such companies is as likely to be accrued by the company in other countries as it is to accrue to the UK. HM Treasury referred to this as the 'export' of UK-generated intellectual property, noting that it occurred at some cost to the tax payer in the UK (HM Treasury, 2000: 13). A third is that PSREs such as HRI whose research has traditionally been directed at the needs of the fragmented sectors (i.e. the many, small-scale horticultural growers) may find it much more time-consuming and difficult to attract industry funding than those such as JIC. However, even when PSREs establish links with multinational companies those links can be threatened by mergers and restructuring (Section 3.2.3).

The need for the public sector to attract industry funding means that priority is being given to marketable products and techniques rather than to 'systems' and 'public goods'. For example, the scientists working on nitrogen fixation at the JIC (with the prospect of reducing the need for inorganic nitrogen fertilizer and reducing nitrogen pollution) have been encouraged by BBSRC to redirect their expertise towards herbicide and antibiotic tolerance (Section 3.1.5). The PSREs are compiling inventories of research with commercial potential (e.g. Section 3.3.3), which may mean that research that was formerly disseminated freely to industry as whole will in future be available only to one company. JIC have shown how this problem can be partly overcome by placing restrictions on a sponsor company's use of JIC's intellectual property (Section 3.1.3). The case studies suggest that the large agri-biotechnology companies are particularly interested in the public sector research expertise in cereals (Sections 3.1.3 and 3.2.3), in sharing the expense of costly equipment, and in learning new skills and techniques (Section 3.1.3).


Compared with the goal of 'wealth creation', the goal of improving the 'quality of life' is not well articulated. However, IACR's mission statement makes explicit reference to environmental and social sustainability. IACR's director referred to the wealth creation/quality of life dichotomy but believed IACR's research could inform both strategies, that is, the improved understanding as a result of the research could be applied equally to either intensive or extensive agricultural methods.

The case studies show that the public sector research institutes are strongly influenced by Government policies, as might be expected. This is most marked in the case of the MAFF-sponsored institute, the HRI. Almost 60% of HRI's funding comes from MAFF, leaving HRI researchers very vulnerable to changes in MAFF policy (postscript: late in 2000, HRI had to cut 150 posts). The BBSRC-sponsored institutes are one step removed from Government policies, as shown in Figure 1. Their BBSRC core funding gives them slightly more flexibility. One example of this is the way that IACR has used BBSRC core funding to ensure that the jobs of its key scientists are secure, rather than dependent on MAFF funding. IACR's director confirmed the point made by Martin (1998), that even in the BBSRC-sponsored institutes a significant proportion of research income is linked to the sponsor's priorities, so that the scope for the PSRE to determine the direction of its research is limited (Section 3.2.4).

Policy pressures on the public sector to secure more industry funding is putting 'quality of life' and public-interest objectives at risk. There is already a view that the public sector research establishments can no longer be relied on as a source of independent expertise, because their results and advice may be compromised by industry funding. This is leading the public

ANNEX E7

and the media to rely more on environmental groups as their main source of information about controversial issues such as crop and food biotechnology and pesticide use. Policies that enabled and encouraged public sector research establishments to ring-fence their public-interest research activities from the rest, and safeguard them from budgetary cuts, might begin to reverse this trend.



References

- Cohen, W.M. and Levinthal, D.A. (1990). Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* 35, 128-152).
- DETR (Department of the Environment, Transport and Regions) (1999). The Government's Response to the Fifth Report of the Select Committee on Environmental Audit. Genetically Modified Organisms and the Environment: Co-ordination of Government Policy. www.environment.detr.gov.uk/response/gmo99/index.htm.
- Farrar, S. (2000) Budget hike masks cut to science base. *Times Higher Education Supplement*, p. 1.
- HM Treasury (1999) *Creating Knowledge Creating Wealth. Realising the Economic Potential of Public Sector Research Establishments*. www.hm-treasury.gov.uk/docs/1999/baker.html, accessed 12/10/2000.
- JIC (undated) *John Innes Centre Corporate Plan 1996-2001*. Norwich: JIC.
- Martin, P. A. (1998) Inventory and Analysis of Biotechnology Programmes and Related Activities in all Countries Participating in the Biotechnology Programme 1994-1998: National Report of the UK.
- McMillan, G.S., Narin, F. and Deeds, D.L. (2000). An analysis of the critical role of public science in innovation: the case of biotechnology. *Research Policy* 29, 1-8.
- Robertson, V. (2000) Extra Support for organic converts. *The Herald*, 14 July.
- Thirtle, C., Palladino, P. and Piesse, J. (1997) On the organisation of agricultural research in the United Kingdom, 1945-1994: A quantitative description and appraisal of recent reforms. *Research Policy* 26:557-576.
- UK Government (1993) *Realising Our Potential: A Strategy for Science, Engineering and Technology*, Cm 2250, London: HMSO.
- Zeneca (1998). Zeneca invests £50M in wheat laboratory and research collaboration. Press Release. http://www.zenecaag.com/news/press_ch.asp?theDate=16-09-98&yr=98, accessed 13/12/99.
- PSRE reports and websites
- HRI (1998?). Horticulture Research International Corporate Plan 1998-2003.
- HRI (1999?). Horticulture Research International Company Report 1997-99
- JIC (undated). John Innes Centre Corporate Plan 1996-2001.
- JIC (1999). John Innes Centre and Sainsbury Laboratory Annual Report 1998/1999.
- IACR (1999?). Annual Report 1998.
- SCRI (1999). Scottish Crop Research Institute Annual Report 1998/1999.
- HRI website: www.hri.ac.uk
- JIC website: www.jic.bbsrc.ac.uk
- IACR website: www.iacr.bbsrc.ac.uk
- SCRI website: www.scri.sari.ac.uk/
- Interviews
- Professor M. Gale, Acting Director, JIC.
- Professor R. Thorneley, Biological Chemistry Department, JIC.
- Professor Denis Murphy, Head of Brassica and Oilseeds Department, JIC.

ANNEX E7

Professor I. R. Crute, Director, IACR.

Stephen James, Assistant Director External Relations, IACR

Judy Mann, International Liaison Officer, IACR.