ANNEX F1

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

Effects of Innovation in the European Agrochemical and Seed Sectors on Employment and Competitiveness

Objective 3 Report

Annex F1

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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.

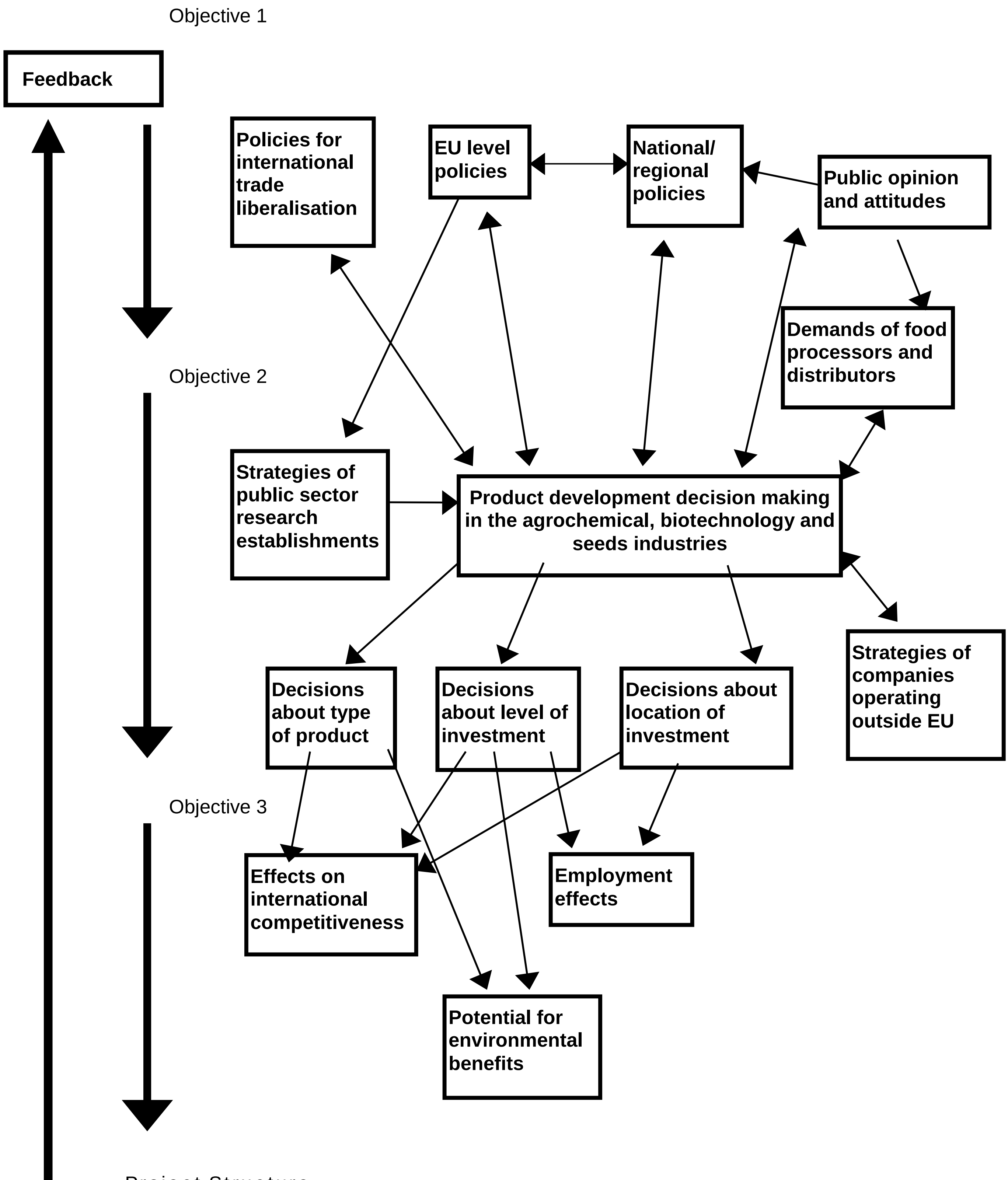
The range of policies and other influences studied includes:

- 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.

ANNEX F1



Project Structure

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1. Introduction

Advanced biotechnology, based on genetic engineering, provides new technical opportunities for developing improved crop seed varieties and new types of plant protection products (PPPs) such as herbicides, fungicides and insecticides. These technical opportunities can potentially influence the entire agro-food production chain, from the suppliers of agricultural inputs to food processors and retailers. This could change both employment and the competitiveness of firms in the European agro-food sectors. At the same time, new seed varieties and PPPs, developed either through advanced biotechnology or conventional techniques, could result in environmental benefits that could further the goal of sustainable agriculture.

Examples of new technical innovations with possible environmental benefits include the development of herbicide, drought, and pest resistant seeds. Herbicide resistant crop plants such as Liberty Link™ offer several possible environmental benefits from replacing more toxic herbicides with less toxic substances and less herbicide use per unit of output[1]. Pest resistant seeds can both reduce the need for pesticides and increase crop yields, while improved quality characteristics such as a higher sugar content in sugar beets can reduce the amount of farmland required to produce sugar. Improvements in oilseeds and biomass crops could replace petroleum and coal in the lubricant and energy generation industries. One of the largest potential environmental benefits is from improved animal feeds. Phytase-reduced grain for animal feed, for example, could reduce phosphate pollution of water from animal manure.

Environmentally beneficial innovations in crop protection products include bio-pesticides and less toxic chemical pesticides that are cost-competitive with pest resistant seeds. Innovation in the seed and crop protection sectors are increasingly complementary because of the development of seed varieties that are linked to specific chemicals such as herbicides or fungicides, or chemicals that can activate or inactivate specific genes.

The challenge for European policy makers is to encourage the potential environmental benefits of new agricultural technologies while simultaneously improving the competitiveness of European agriculture and related industries[2]. Another policy goal is to encourage innovation that can maintain or increase employment in the agro-food chain[3].

Advanced biotechnology, based on genetic engineering, is generally viewed by European policy makers as a new technology that will have a positive effect on employment. In the introduction to the 1997 Ernst and Young report, "*European Biotech 97: A New Economy*", Bruno Hansen, of DG XII, states that biotechnology "will lead to job creation and employment of a skilled workforce (p ii)". He goes on to note that "industries based on traditional life sciences support some 19 million European jobs". The implication is that biotechnology could have a significant impact on European employment.

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[1] There is conflicting evidence over the environmental benefits of current herbicide tolerant (HT) crops (Economic Research Service, 1999), but the principle remains.

[2] The importance of environmental goals for European policy are listed in Articles 130R, S, and T of the Maastricht Treaty. The importance of both environmental and employment goals are restated in the Amsterdam Treaty as a major objective: to promote economic and social progress and a high level of employment and to achieve balanced and sustainable development".

[3] Several European policy documents, including the *Green Paper on Innovation* and the *First Action Plan for Innovation in Europe*, make job creation one of the primary goals of innovation policy. The introduction to the *First Action Plan* states: "A demand for new products and services is emerging. The ability to innovate in order to satisfy these new needs is a precondition for the future creation of jobs in Europe. This ability is also necessary in order to maintain competitiveness and employment in other sectors of activity (p.2)".

Yet, it is not clear what the impact of agricultural biotechnology on employment will be, even though estimates of the employment effects of agro-biotechnology have been available for at least 15 years. As an example, Watanabe identified the main employment issues in a 1985 article and predicted that the application of biotechnology to agriculture would have significantly greater economic impacts than pharmaceutical applications. He also argued that the direct employment effects of biotechnology (employment in the firm that develops the innovation) were likely to be marginal and limited to R&D and production in a 'small number of highly capital- and science-intensive establishments in industrial countries'. In contrast, he predicted greater indirect employment effects (in supplier and user firms that did not develop the innovation) from the use of products containing biotechnology.

Many of the possible environmental benefits from innovation in the seed and agrochemical sectors are due to a reduction in agricultural inputs, which should reduce employment somewhere in the agro-food chain through indirect employment effects. Conversely, employment could increase if European firms are able to capture a larger share of the global market for PPPs and seeds, which will depend on the competitiveness of these firms. Whether or not innovation in biotechnology or PPPs is likely to increase, decrease, or have no effect on employment depends on the innovation strategies of firms in the agro-food chain, the success of these strategies, the technical opportunities for innovation, and the policy environment.

The purpose of this report, part of a larger research project on *Policy Influences on Technology for Agriculture*, is to provide a qualitative assessment of the effect of current patterns of innovation in the seed and PPP sectors on employment and competitiveness. This report also assesses, where relevant, the impact of current European policy and the effect of environmentally beneficial innovation on employment. The dominant policy issue for firms in the seed sector during the course of this study is the acceptance of genetically-modified (GM) foods by the European public and the *de facto* moratorium on the use of GM crops, which was introduced in the summer of 1999. Both actions have placed the commercialisation of GM crops in Europe on hold.

A range of data sources are used to evaluate these issues. In addition to the published and grey literature, relevant information has been obtained from the following:

- Analyses of relevant questions in previous surveys from Europe and Canada.
- A series of interviews with Europe's largest seed and PPP firms.
- A new survey of European seed and PPP firms.
- An analysis of the European database on field releases of GM organisms.

The existing surveys consist of two innovation surveys in Europe; the first Community Innovation Survey (CIS-1) and the PACE survey of Europe's largest industrial firms; and two Canadian surveys on biotechnology. Appendix A provides brief descriptions of the methodology of the latter four surveys.

The results are presented below in three main chapters.

Chapter Two provides the background context. This includes past trends and current levels of employment in the agro-food chain, estimates of current agro-biotechnology employment, and the general employment effects of the innovation strategies of food processors. Some of the discussion in Chapter Two refers to basic concepts such as labour-saving innovation or direct and indirect employment effects. These basic concepts are discussed in Appendix B, which provides an overview of the theoretical and empirical literature on the relationship between innovation on employment.

Chapter Three evaluates the effect of shifting innovation and business strategies on employment. The data on innovation strategies is largely drawn from a series of interviews with the main seed and PPP firms in Europe.

Chapter Four provides the results of a survey of European seed and agrochemical firms, conducted in May and June of 1999. The survey evaluates the effect of different innovation paradigms on competitiveness and employment over the short-term future[4].

Finally, Chapter Five summarises the main results from Chapters Two through Four.

2. MAIN EMPLOYMENT TRENDS IN THE AGRO-FOOD CHAIN

2.1 The Agro-Food Chain

The seed and agrochemical sectors are part of an agro-food chain that runs from the suppliers of agricultural inputs (other than land and water) to the final consumer of agricultural products. The basic structure of the agro-food chain is given in Figure 2.1.

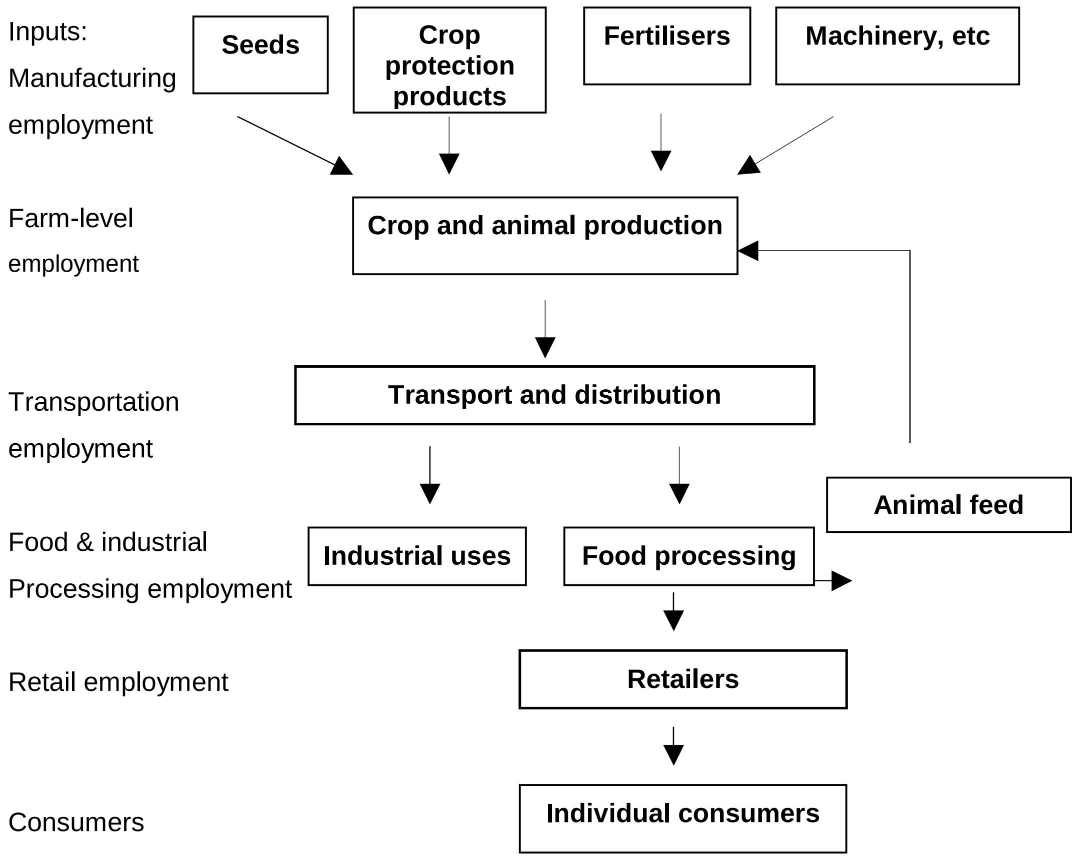

Figure 2.1 Agro-food chain

The innovative activities of firms in the seed and PPP sectors can influence employment patterns at four levels of the food chain: manufacturers of inputs, on the farm, transportation and distribution, and food and industrial processing. A major feedback loop in the agro-food chain is the production of animal feed, using grains such as maize or barley, which is then used in meat and dairy production.

[4] Several publications are based, in part, on the survey results. See Arundel *et al* (2000); Arundel (2001), and Arundel (2000).

The key decision maker for the adoption of innovations developed by the seed and crop protection sectors has been the farmer and not the final consumer, the food processing industry, or retailers. However, the latter can influence the price that the farmer can expect from the sale of these crops and therefore the motivation to adopt specific seed varieties or crop protection products. Who acts as the key decision maker could also change in the future in response to innovation. This could alter employment patterns.

2.2 Employment Trends in Agriculture and Manufacturing

An evaluation of the effect of innovation in the seed and PPP sectors must be placed in the perspective of a long-term decline in the share of agriculture and manufacturing in European employment since the early 1970s. As an example, employment in agriculture, fishing and forestry declined by 42.5% in France between 1977 and 1992, while manufacturing employment declined 29.2% (Meijers, 1997). These declines are due to several factors: labour-saving innovation, a relative fall in demand for agricultural and industrial products compared to services, and the outsourcing of key activities to service firms (see Appendix B).

Between 1985 and 1997 the share of the workforce in agriculture declined in all member states of the EU by an average of 35.3%, ranging from 54.1% in Spain to 17.4% in the UK (OECD, 1999). The share of agricultural employment in 1997 was much higher in Greece (20.3%), Ireland (10.4%), Portugal (13.7%) and Spain (8.4%) than in the other EU countries (OECD, 1999). The lowest share of agricultural employment in 1997 is in the United Kingdom (1.9%), Belgium (2.3%), Luxembourg (2.6%), and Sweden (2.8%). The decline in agricultural employment in Europe is partly due to higher productivity.

Total agricultural output has increased in the European Union between 1985 and 1997 by 9%, from 224.9 billion USD to 245.2 billion USD (using 1990 dollars), which is less than a 1% annual increase. However, although output has increased, the gross value-added of European agricultural output (at market prices) has declined by 10.7% between 1990 and 1997. One cause of the decline is an increase in the cost of manufactured inputs such as fertilisers and pesticides and the cost of other inputs such as maintenance and animal feed. The increase in input costs has largely been met by a more than two-fold increase in subsidies, from 15.4 billion Ecus in 1990 to 36.7 billion Ecus in 1997.

Figure 2.2 gives the percentage change in all manufacturing employment in Europe between 1978 and 1992[5] and the change for several manufacturing sectors that are affected by developments in agro-biotechnology and agro-chemicals. These includes sectors such as food processing and beverages that are potential users of materials produced through agro-biotechnology and the agro-chemical sector (which includes PPPs plus fertilisers and plant growth regulators). The pharmaceutical sector is included because many of the key bio-technologies are used by both pharmaceutical and agro-biotechnology firms.

[5] Employment data is obtained from the OECD's STAN database for 13 EU countries combined, excluding Ireland and Luxembourg which are not included in STAN. The series ends at 1992 because of incomplete data for several important countries such as Italy. The data for the pharmaceutical sector excludes Belgium and Italy, in addition to Ireland and Luxembourg.

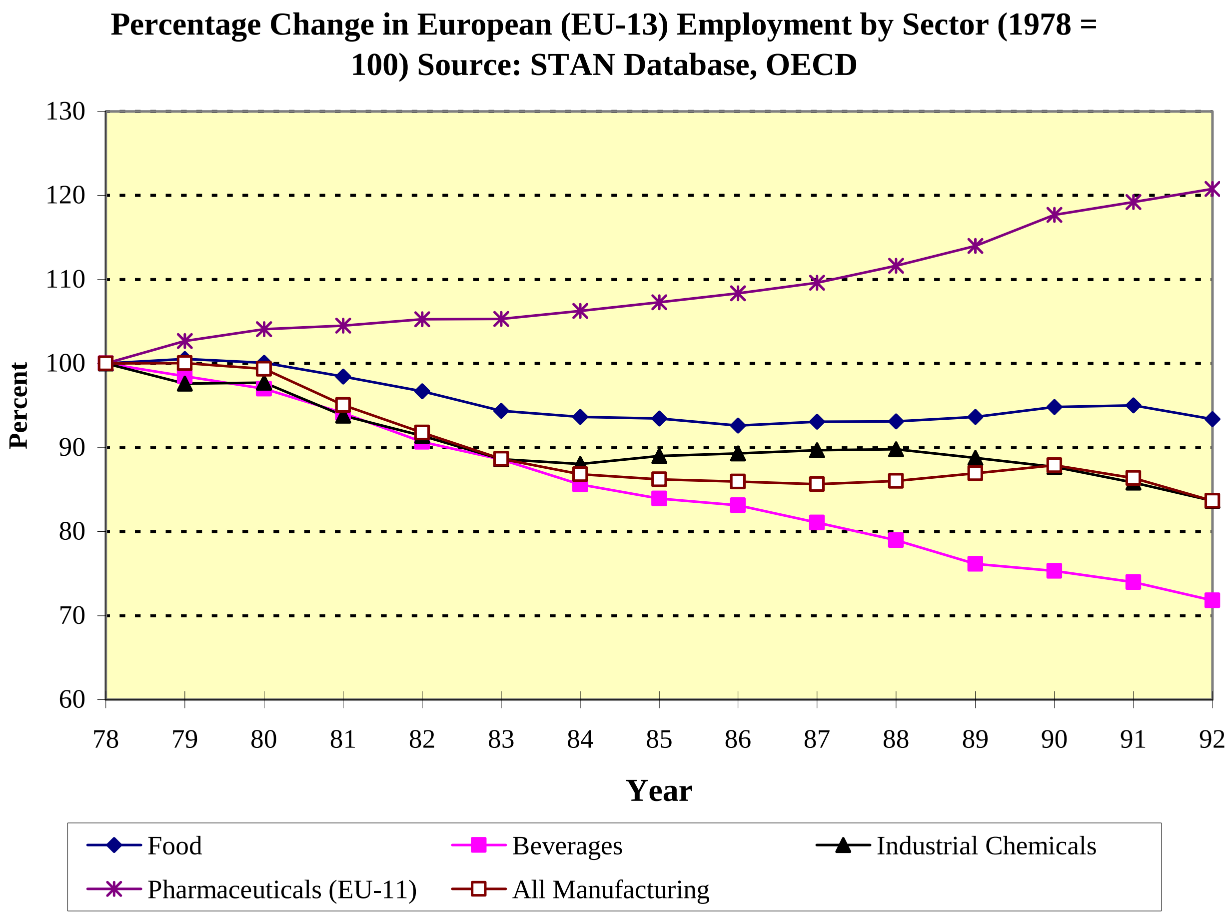

Figure 2.2

Employment has declined in each of these manufacturing sectors, with the exception of a 20% increase in employment in the pharmaceutical sector. The largest percentage decline is in beverages, where there are 28% fewer employees in 1992 than in 1978. In contrast, employment in food processing declined to only 94% of 1978 levels.

Employment in PPPs should be affected by agro-biotechnology products that either reduce the need for PPPs or which link specific crop varieties to proprietary herbicides. In Figure 2.2, PPPs are included in the 'industrial chemicals' sector, which also includes basic industrial chemicals and synthetic resins and plastics[6]. Since only a small percentage of total employment in industrial chemicals is likely to be due to PPPs, it is not possible to use the STAN data to determine trends within the PPP sector alone. However, an analysis of the rates of product and process innovation in each sub-sector of the chemical industry suggests that employment in agro-chemicals, which includes PPPs, growth regulators, and other

[6] The STAN data uses the second revision of the International Standard Industrial Classification (ISIC) series. The three digit class of industrial chemicals (ISIC 351) includes basic industrial chemicals (3511), agro-chemicals (3512), and synthetic resins and plastics (3513) (UN, 1968).

related chemicals, could be increasing even though overall employment is decreasing in basic chemicals (Albach et al, 1996)[7].

Although the same advanced biotechnologies are used in both the agro-food and pharmaceutical sectors, the employment effects of policies of relevance to agro-biotechnology could have a greater impact on employment than policies of relevance to the pharmaceutical sector. This is because employment in the pharmaceutical sector, even though it is increasing, is much smaller than employment in the food processing and agrochemical sectors. Pharmaceutical employment accounted for only 1.6% of total manufacturing employment in 1992, while food processing accounted for 9.6% of manufacturing employment and chemicals for another 9.7%.

2.2.1 Market Trends

Slow population growth within the European Union places a major constraint on the future growth of the European market for seeds and PPPs. This means that employment growth in these sectors will depend on exports. Astra-Zeneca predicts that the global market for agrochemical products will increase from 30 billion USD today to 75 billion in 2020, largely as a result of an increase in demand in Asia and Latin America. Market growth, however, depends on an increase in average incomes in the developing world, leading to an increase in demand for meat and dairy products (OECD, 2000)[8]. The current global market for seeds is much smaller, at approximately 5 billion USD.

European agrochemical firms will likely enter new markets through a combination of exports and establishing foreign manufacturing plants. This could slightly shift the distribution of European employment in this sector towards management and R&D functions. Conversely, there are limits to the ability of seed firms to serve export markets with European grown seed, since seed varieties need to be adapted to local market conditions. This means that many seed varieties are both tested and grown locally. The result is that the employment effects in Europe from expansion into Asian or Latin American seed markets is likely to be limited to upstream R&D and management.

2.3 Agro-Biotechnology Employment

The most important innovation in the seed sector is the use of advanced biotechnology to develop new seed varieties. This development has attracted an enormous amount of interest by economists and policy makers in the past decade. Surprisingly, however, there are no entirely satisfactory estimates of past and current employment in agro-biotechnology or in sectors that apply agro-biotechnology innovations. Most of the available information on biotechnology employment is limited to pharmaceutical applications of biotechnology. The lack of information on agro-biotechnology employment in Europe was one of the main reasons for the survey of European seed firms, as presented in Chapter Four. This section summarises other estimates of agro-biotechnology employment and provides a composite estimate of agro-biotechnology employment in Europe.

2.3.1 Ernst and Young estimates of agro-biotechnology employment

The Ernst and Young reports on biotechnology in the United States and in Europe are widely used to track the development of the biotechnology sector. These reports estimate that the number of biotechnology employees in entrepreneurial firms in Europe has been growing

[7] The decline in employment in basic chemicals to 84% of 1978 levels could mask an increase in agrochemical employment because basic chemical firms account for an estimated 82% of European firms active in industrial chemicals (Albach et al, 1996, p 42) and are therefore likely to account for the majority of employment as well.

[8] A substantial fraction of all crop output is used to feed farm animals. In the European Union, the share of crops out of total agricultural output ranges from 30% in Denmark to 60% in Spain. The rest is accounted for by meat and dairy (OECD, 1999).

rapidly by approximately 40% per year. These results are shown in Table 2.1, which also gives comparable data for the United States.

Table 2.1 Employment in entrepreneurial biotech firms

	EUROPE		US	
Year	# Firms	Employees	# Firms	Employees
1995	584	17,200	1,308	108,000
1996	716	27,500	1,287	118,000
1997	1036	39,045	1,274	140,000
1998		45,823	1,283	153,000

Source: Ernst and Young (1997, 1997a, 1998, 1998a, 1999)

Ernst and Young (1997) also estimated the number of European agro-biotechnology (agbio) and food processing firms in 1996 that are involved in biotechnology. The results are given in Table 2.2. Using the mid-points for firm size, these results estimate a total of 5,625 jobs among entrepreneurial biotechnology firms in the agbio and food-processing sectors. Approximately 22,000 of the remaining employees are in firms active in pharmaceutical applications. To put these figures in perspective, this is equal to 8% of employment in the pharmaceutical sector in 1992[9], while the 5,625 jobs in agro-biotechnology and food processing is less than 0.2% of 1992 employment in the food processing sector alone. However, several limitations of the Ernst and Young methodology are likely to substantially underestimate agbio employment in Europe[10].

Table 2.2 Estimated number of dedicated biotechnology firms in agro-biotechnology and food processing in Europe in 1996

	Total	Large (150-500)	Medium (50-149)	Small (1 –49)
Agro-biotech	58	4	12	42
Food processing	34	2	7	25

Source: Ernst & Young (1997)

2.3.2 EuropaBio estimate of agro-biotechnology employment

A 1997 report for EuropaBio provides a more interesting approach to that taken by Ernst and Young by estimating the total number of current European jobs that are ‘dependent’ on agricultural and food applications of biotechnology. The report also estimates future employment levels as a consequence of several scenarios based on policy and market demand (EuropaBio, 1997; Burke and Thomas, 1997). Unfortunately, the methodology used in this study substantially overestimates the impact of agro-biotechnology on employment.

The EuropaBio report estimates the sales value of all products produced using agro-biotechnology, either directly or indirectly. This figure is then divided by the average sales per

[9] Limited to 11 EU countries with data on pharmaceutical employment.

[10] The Ernst and Young estimates exclude firms with more than 500 employees, such as established pharmaceutical or agro-biotechnology firms, and smaller firms that are not dedicated to the biotechnology sector. These limitations will be particularly severe in the European seed sector, where biotechnology expertise is concentrated in large firms. The continuing trend towards consolidation in the seed and agro-chemical sectors in both the United States and Europe (Ernst & Young, 1998, 1998a) is further shifting the locus of agro-biotechnology expertise to large European firms such as Novartis, AgrEvo, and Aventis (See Chapter Three).

worker in the EU. For example, total sales of biotechnology-based products in 1995 is estimated at 40 billion Ecus while the sales produced by each average job (total European GDP/total European employees) is 146,000 Ecus. The 40 billion in sales divided by 146,000 ECUs gives an estimate of 588,000 agro-biotechnology jobs in 1995. Several scenarios show how this number could reach 3.65 million by 2005.

There are two major problems with this method. The first is that both sales and value-added per employee varies widely by sector. As noted elsewhere by one of the authors (Thomas, 1998), value-added is a better measure because it avoids the distortion of sales by intermediary products[11]. The second problem, which is considerably more important, is due to attributing 100% of product sales that contain a biotechnology component to biotechnology[12]. For example, the full sales value of cheese produced using chymosin would be attributed to biotechnology. By implication, this means that all employees in such cheese factories are also '*biotechnology-dependent*'.

As an analogy, this is equivalent to estimating the value of the computer chip industry by assigning *all* output and *all* employees of *all* products and services that contain a computer chip *or* depend on one somewhere to the computer chip industry. In Europe today, practically all services and manufactured products either contain a chip or use them somewhere in the manufacturing process or in the provision of the service. Therefore, using the EuropaBio methodology would probably estimate that almost all employment is computer-chip '*dependent'.*

The authors of the EuropaBio report argue that their method is reasonable, since the firm would lose its competitive advantage and go bankrupt without the use of the biotechnology at some crucial point. This is unrealistic. A cheese maker can still use rennet instead of chymosin. This might increase costs slightly or influence consumer preferences, resulting in a small decline in profits or output, but it is not likely to cause bankruptcy. This is one of the basic rules of innovation: there is no one solution to any problem.

In effect, EuropaBio reassigns many *existing* jobs to biotechnology. The future scenario estimates, such as 3.65 million jobs in 2005, are similarly based on the reassignment of existing jobs to the agro-biotechnology sector.

2.3.3 Agro-biotechnology employment in Canada

The best available data on current agro-biotechnology employment is from two Canadian surveys: the *Survey of Biotechnology Use in Canadian Industries – 1996* and the *Biotechnology Firm Survey – 1997*[13]. Both surveys were conducted by Statistics Canada. Their main relevance to Europe is as an example of current best practise in obtaining employment data for a developing technology[14].

The biotechnology survey results for 1996 are for mid to large manufacturing and resource-extraction firms that apply biotechnology while the results for 1997 are for the main R&D performing biotechnology firms in Canada[15]. The 1996 survey collects data on the number of

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[11] The authors could have provided a better estimate by using the STAN database to calculate value-added per employee in relevant sectors such as food processing.

[12] Thomas (1998) notes that 'crucially, it was assumed that the use of biotechnology is central to sustain the overall competitiveness of the manufacturing process in question...on the basis of these assumptions, the impact of biotechnology was valued as being 100% of the manufacturer's sales turnover' (p. 11).

[13] The date of each survey refers to the year for which the results are valid. For example, the *Survey of Biotechnology Use in Canadian Industries–1996* was conducted in 1997 and collected data for firm activities in 1996. The results of a third survey, conducted in early 2000, are not yet available.

[14] Statistics Canada's experience is being used by the OECD to develop internationally comparable methods of obtaining data on biotechnology use, applications and employment. A related survey has already been conducted in France.

[15] For details of the methodology of each survey, see Appendix II.

employees in each firm that 'work with biotechnology' by educational level while the 1997 survey collects data on the number of employees, in each of seven activities, that are 'engaged in biotechnology activities'. These seven activities are combined into four groups: R&D and allied activities such as clinical and regulatory affairs, manufacturing, marketing, and management.

The results of the 1996 survey indicate that 10.2% of agro-food manufacturing firms (food and beverage processing plus agro-chemicals) in Canada apply at least one of nine biotechnologies of relevance to agro-food applications and that this number has been increasing by 5.2% per year since 1979 (Arundel, 1998; Arundel and Rose, 1999). In 1996, these firms accounted for 18% of total employment among agro-food manufacturers.

The estimate that 18% of agro-food manufacturing employees in Canada work for a firm that uses agro-biotechnology is similar to the estimate, derived from the EuropaBio study, that 16.2% of European food processing employment is 'biotechnology' dependent[16.] However, analysis of the results of the 1996 and 1997 Statistics Canada surveys on the number of employees that actually work with or are engaged in biotechnology indicates that approximately 1% of the total number of employees in the Canadian agro-food manufacturing sector are involved in biotechnology in some way[17.] This shows that there is a very wide gap between the number of jobs in firms that use biotechnology somewhere within their operations and the number of jobs that directly involve biotechnology.

Furthermore, there is a negative correlation between firm size and the percentage of employees that are engaged in biotechnology, even among core biotechnology firms, as shown in Table 2.3. For agbio firms, the percentage of employees that are engaged in biotechnology fall from 88% for firms with fewer than 10 employees to 27% for firms with more than 100 employees.

Table 2.3 Average percentage of employees within Canadian 'core' biotechnology firms that are engaged with biotechnology

	Firms active in agbio		Firms active in other biotechnologies	
No. employees	N	Percent	N	Percent
< 10	10	88%	39	88%
10 – 49	29	83%	55	88%
50 – 99	–		17	79%
100 +	11	27%	27	38%
p for trend		< 0.001		< 0.001

Source: Statistics Canada, Biotechnology Firm Survey – 1997. Analysis by the author.

These results highlight the problems with estimates that assign all of a firm's employees to biotechnology, including the estimate, based on Ernst & Young's figures, of 5,625 agro-food biotechnology jobs in Europe. Although this method is reasonably accurate for very small, dedicated biotechnology firms, the amount of error increases with the average firm size.

The two surveys were used to estimate the total number of biotechnology jobs in Canada between 1996 and 1997. The best estimate is of 11,500 jobs, of which 7,000 (61%) were in firms that performed biotechnology R&D. Of the biotechnology employment among R&D performing firms, 22% were in agriculture or food processing (Arundel and Rose, 1999b).

[16] EuropaBio estimates that there were 588,000 agro-biotechnology dependent jobs in 1995 in the food-processing sector. This is equal to 16.2% of total European employment in this sector in 1995.

[17] Approximately 60% of biotechnology employees in the agro-food sector are employed by mid to large firms.

2.3.4 Total agro-biotechnology employment in the European Union

A very rough composite estimate of European agro-biotechnology employment can be constructed using the Ernst and Young estimate of 5,625 agro-biotech jobs in dedicated agro-biotechnology firms with less than 500 employees, the Statistics Canada estimate of a 1% rate for biotechnology jobs among medium to large firms in food processing, and the survey estimates (see Tables 4.5 and 4.12) of the percentage of research in seeds and PPPs that is spent on advanced biotechnology.

In 1995, there were approximately 3.3 million jobs in the European Union in food and beverages and 0.9 million jobs in industrial chemicals (OECD, 1998). The latter includes basic chemicals, fertilisers and resins, and synthetic materials. Only about 3% of these jobs, or 27,000, would have been in PPPs.[18] The 1% rate applied to the 3.3 million food processing jobs estimates 33,000 biotechnology employees. In 1999, 7% of the research expenditures of PPP firms were in chemical-crop combinations that would involve biotechnology. Assuming that this percentage applies to total employment in 1995, 1,330 of the 27,000 PPP jobs in 1995 would have involved biotechnology. There is no estimate of employment in seed firms for 1995, so 1999 data from the survey will have to be used. In total, 26.7% of the research budget was spent on genetic engineering plus assisted conventional breeding, which uses several techniques developed for genetic engineering. Using the same ratio between PPP employment in the survey and all of the European Union results in an estimated 27,000 jobs in seeds, of which 7,209 (26.7%) could be related to advanced biotechnology.

The total estimate of agro-biotechnology employment for the late 1990s is therefore 47,164: 5,625 in dedicated agro-biotechnology firms, 33,000 in food processing, 1,330 in the PPP sector, and 7,209 in seed firms. The decline in food processing jobs since 1995 and some double counting of dedicated agro-biotechnology firms will overestimate employment. Conversely, the number of dedicated agro-biotechnology firms and the percentage of biotechnology jobs in food processing could have increased since 1996. Therefore, the estimate can probably be rounded up to about 50,000 direct agro-biotechnology jobs in 1999, which is about 0.2% of total manufacturing employment in the EU. This shows that the employment effects of agro-biotechnology are likely to be mostly due to indirect effects on the agro-food chain, given that there are over 3 million jobs in food processing alone.

2.4 Agro-Biotechnology and Job Skills

Innovation can affect not only total employment, but the distribution of employment among different types of job skills (see Appendix B). Existing research suggests that most biotechnologies, including agro-biotechnology, require highly skilled labour (Hayward *et al*, 1992). This could lead to a shift in employment in the seed and PPP sectors towards higher paid jobs. However, this conclusion is largely based on the need for R&D staff by small, dedicated biotechnology firms, whereas the predominant effect of agro-biotechnology on skills is likely to be in the agriculture and food-processing sectors (Watanabe, 1985; Burke and Thomas, 1997).

2.4.1 Farm-level skills

Agricultural skill levels are partly formed by the type of method used to grow crops. For example, intensive agriculture based on the use of standardised pesticide spraying regimes requires lower skill levels than Integrated Pest Management (IPM), which is based on ‘wait and see’ crop protection methods, the use of biological controls, and the application of limited amounts of targeted pesticides. IPM, in effect, replaces pesticide use with ‘knowledge’ (Cowan and Gunby, 1996). The effect of agro-biotechnology on skill levels in agriculture will depend on which of several possible innovation trajectories are followed.

[18] The survey (see Chapter 4) estimates that there were approximately 20,000 jobs in PPPs in six EU countries in 1999, which is 3% of all jobs in industrial chemicals in 1995 in the same six countries.

Herbicide tolerant (HT) crop varieties, which have attracted the most agro-biotechnology investment to date by seed firms (see section 3.2.2), are likely to reduce skill requirements. A review of research in this area by DG Agriculture (2000) shows that one of the primary reasons for the rapid adoption of HT maize by American farmers is due to their convenience. In contrast to 'information rich' IPM, HT crops have a wider window for herbicide application and greater ease of use. Both factors reduce the need for farm-level skills. An innovation trajectory based on pest-resistant crop varieties could either reduce skill requirements, for example if the variety has almost total resistance, or increase skills if the variety is suitable to an IPM regime. A third development is high value-added quality traits which will require identity preservation. This could result is a slight increase in farm-level skills.

In contrast to conditions in the manufacturing sector, where there is a positive correlation over the medium and long-term between skill levels and wages, differences in farm level skills are unlikely to influence total farm incomes, with the exception of IPM. IPM could result in higher income due to a decline in inputs, but at the cost of more time spent gathering information on pest levels. Conversely, HT and similar crops with greater convenience to the farmer could have no effect on income per hectare, but they could increase the farmer's income per hour of work.

2.4.2 Skill levels among agro-food firms

The Statistics Canada survey on biotechnology provides some useful results on the need for skilled labour and labour demand by manufacturing firms in agro-food applications that use biotechnology. The results, given in Table 2.4, show that the adoption of biotechnology is considerably more likely to increase than to decrease skill requirements.

Table 2.4 Effect of biotechnology use on skill requirements among 59 Canadian agro-food firms

	Percent reporting each outcome	
Effect of adoption	Firms	Employee-weighted
Increases skill requirements	22.0%	43.2%
Decreases skill requirements	6.8%	1.0%

Source: Arundel and Rose, 1999

The employee-weighted results show that 43.2% of agro-food firms report an increase in skill requirements while only 1% report a decrease. The drawback to these results is that we do not know the number of employees that are affected by an increase in skills, whether or not the increase in skills will raise productivity and wages, nor the types of jobs that are affected.

2.5 Labour-Saving Innovation in the Agro-Food Chain

Innovation is a complex systemic process in which the business and innovation strategies of actors throughout a production chain can influence the decisions of all other actors. In the agro-food chain, the innovative strategies of the downstream users of farm products can influence both the development of new seed varieties and PPPs and employment throughout the agro-food chain. As an example, the direct employment effects among food and industrial processors will depend on the importance that these firms assign to reducing their labour costs. Similarly, employment among the upstream suppliers of inputs to the food and industrial processing sectors will be influenced by the innovation goals of downstream food processors. Regulations can also influence investment in innovation by food processors.

This section uses the results of the Statistics Canada, CIS and PACE surveys to evaluate the importance of these factors on the innovation strategies of firms in the food processing sector. Unfortunately, most of these surveys are not detailed enough to permit an evaluation of the importance of these factors to firms that develop or use agro-biotechnology innovations, with the exception of the Statistics Canada survey.

2.5.1 Survey evidence

The results of innovation surveys consistently highlight the importance of labour saving innovation in manufacturing sectors that are current or potential users of agro-biotechnology.

The Statistics Canada survey directly questioned firms about the employment effects of biotechnology. The results show that the adoption of biotechnology by agro-food firms is more likely to reduce direct rather than indirect labour requirements: 20.6% of employee-weighted agro-food firms report a decline in direct labour requirements while 7.6% report a decline in material inputs, which will indirectly reduce labour requirements in supplier firms. Nevertheless, the percentage of agro-food firms that report a decline in either direct or indirect labour requirements is not particularly large[19].

The 1993 CIS contains information for 13,592 innovative European firms on the importance of reducing direct and indirect labour costs as a goal of innovation[20]. These results can be used to estimate the general trend of innovation on employment in sectors that are current or potential users of agro-biotechnology. Direct labour costs are defined as the importance (on a five-point subjective scale) of reducing labour costs within the firm itself. Indirect labour costs concern the importance of reducing material and energy inputs, which will reduce labour requirements in supplier firms. Employee-weighted[21] results are given in Figure 2.3 for direct employment effects and in Figure 2.4 for indirect employment effects, based on the average importance of reducing material and energy inputs[22].

Both Figures 2.3 and 2.4 provide results for the food processing sector (food and beverages combined). For comparison, results are also given for other low technology sectors and for medium, and high technology sectors. The results show that reducing direct labour costs is rated as ‘very important’ or ‘crucial’ by 73% of firms in the food sector, while less than 5% find this goal to be of no or only slight importance. Compared to other sectors, the food sector places the greatest emphasis on reducing direct labour costs. The results for indirect labour costs are similar, with food firms giving this goal more importance than other firms.

The implication of these results for seed and PPP firms is that food processing firms will favour the adoption of new inputs that reduce their input or processing costs. This will limit the prices that food processors will be willing to pay for inputs, which will maintain a

[19] This suggests that most of the advantages of adopting biotechnology, at least so far, are due to other advantages such as an improvement in product quality.

[20] The methodology of the CIS and the analyses given here are provided in Appendix I. The CIS-1 analyses are derived from descriptive analyses conducted in 1995 under an EC European Information Management Systems (EIMS) grant.

[21] The employee-weighted estimates are equal to the percentage of all employees in the sector that work for a firm with the characteristic result.

[22] The average is rounded to the nearest whole integer.

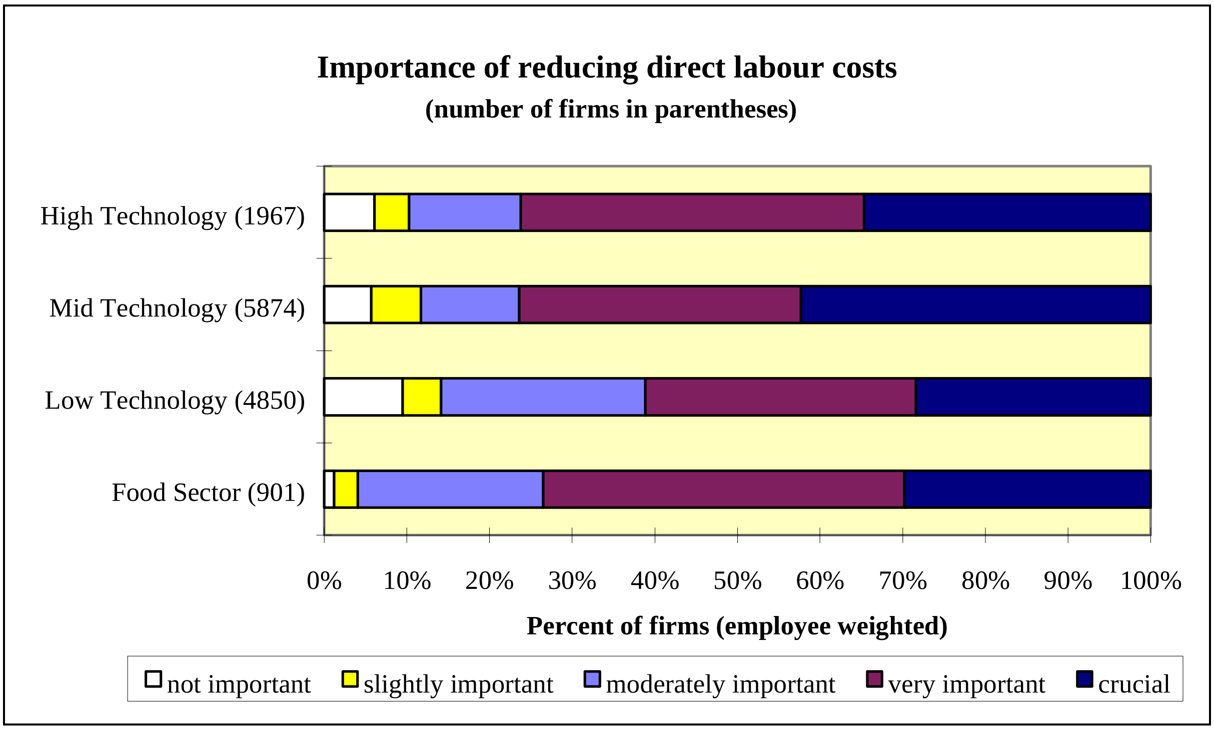

Figure 2.3

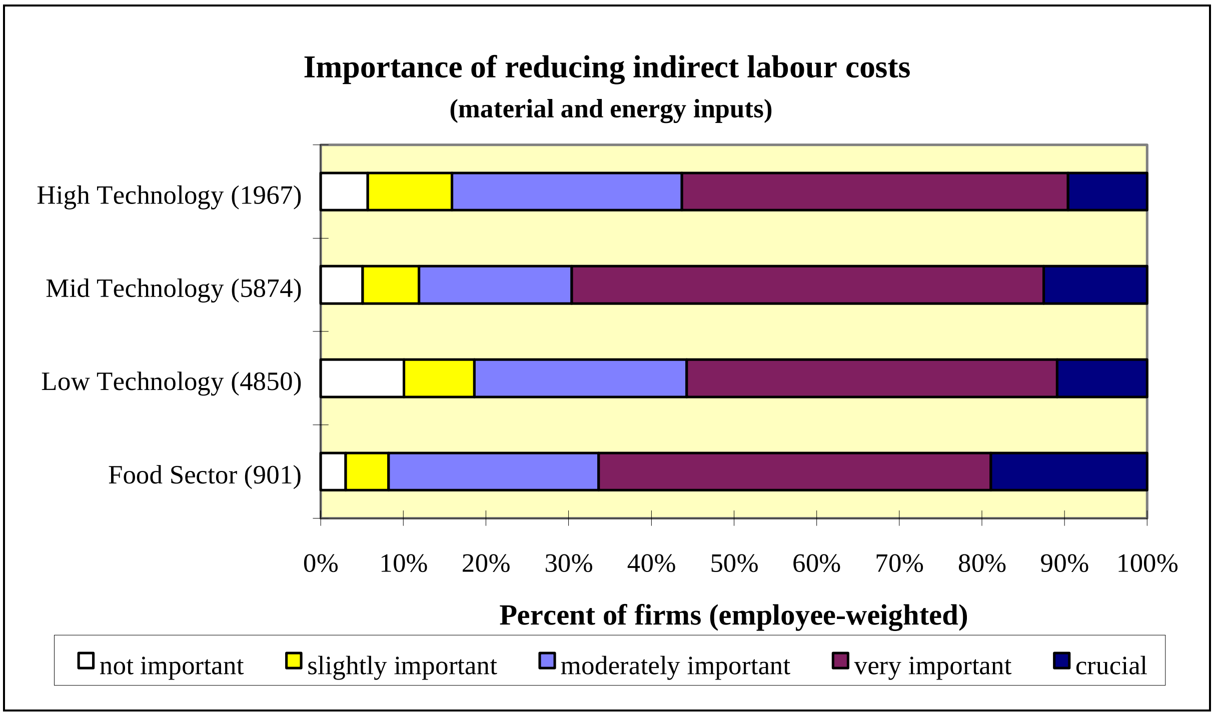

Figure 2.4

downward pressure on the prices that farmers will be willing to pay for inputs, including new seed varieties. In many cases, food processors can substitute one input for another. Depending on the price, poultry feed manufacturers can either use high lysine corn developed through advanced biotechnology or add lysine obtained from industrial fermentation processes (Coaldrake, 1999). This type of price discipline will limit the market for quality traits (see Chapter Three) and aggregate job growth in the agro-food chain.

2.6 Regulation and Innovation

Different types of government regulations could act as a barrier to innovation or prevent firms from being able to profit from their investment in innovation. Either way, regulations could influence the linkages between innovation and employment. Some relevant results on this issue are available for agro-food firms in the PACE survey, as shown in Figure 2.5[23].

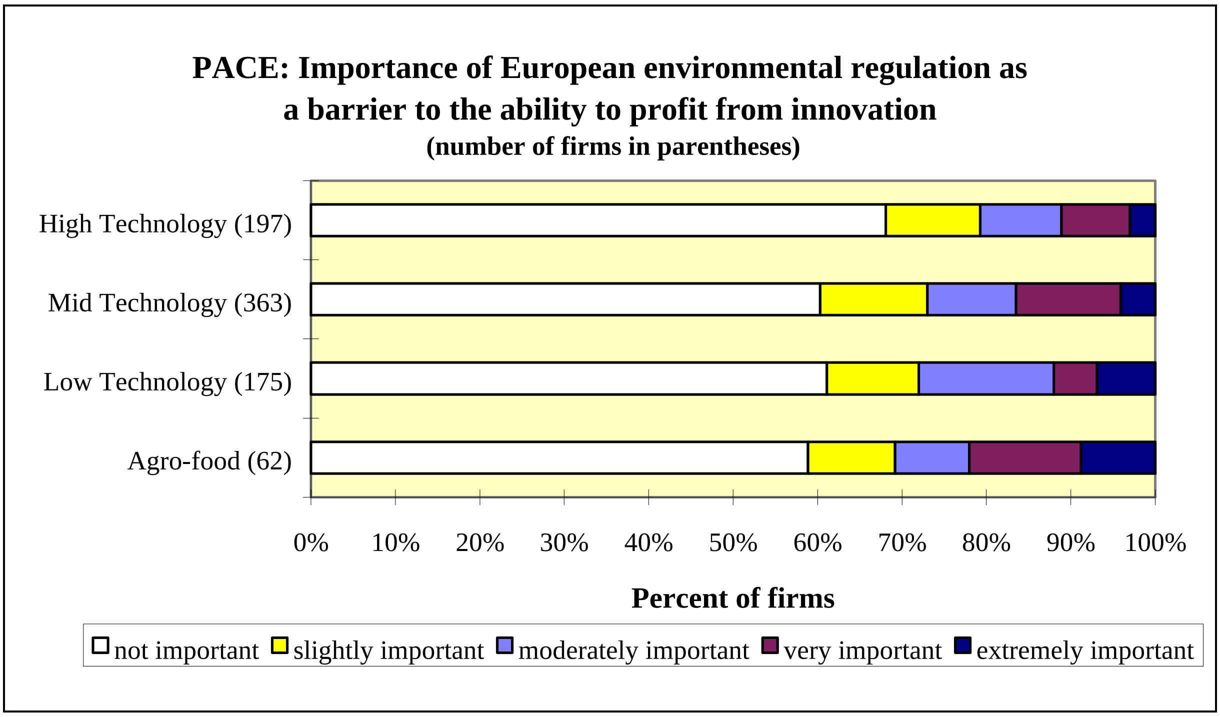

Figure 2.5

The PACE survey asks specifically about the importance of environmental regulation as an obstacle to the ability of the firm to profit from its innovations in European markets. The phrasing of the question therefore refers to *post*-innovation results, which is of direct relevance to regulations, such as those concerning biotechnology, which firms could see as preventing them from introducing innovations such as GM foods. Figure 2.5 shows that the majority of firms, from all technology classes, find that environmental regulations are of no importance (note that these results are not employment weighted, since all respondent firms are large firms). The slightly higher than average percentage of agro-food firms that find such regulations to be ‘very’ or ‘extremely’ important is due to the results for the five agro-chemical and five seed firms in the sample.

Another related facet of regulation is the importance of environmental issues to the choice of a firm’s innovation projects. The CIS asks innovative firms to estimate the importance of reducing environmental damage as an innovation goal. Employee-weighted results for food sector firms and for low, medium and high technology firms are given in Figure 2.6.

[23] See Appendix I for the methodology of the CIS and PACE surveys. The agro-food group in PACE includes 5 agrochemical and 5 seed firms.

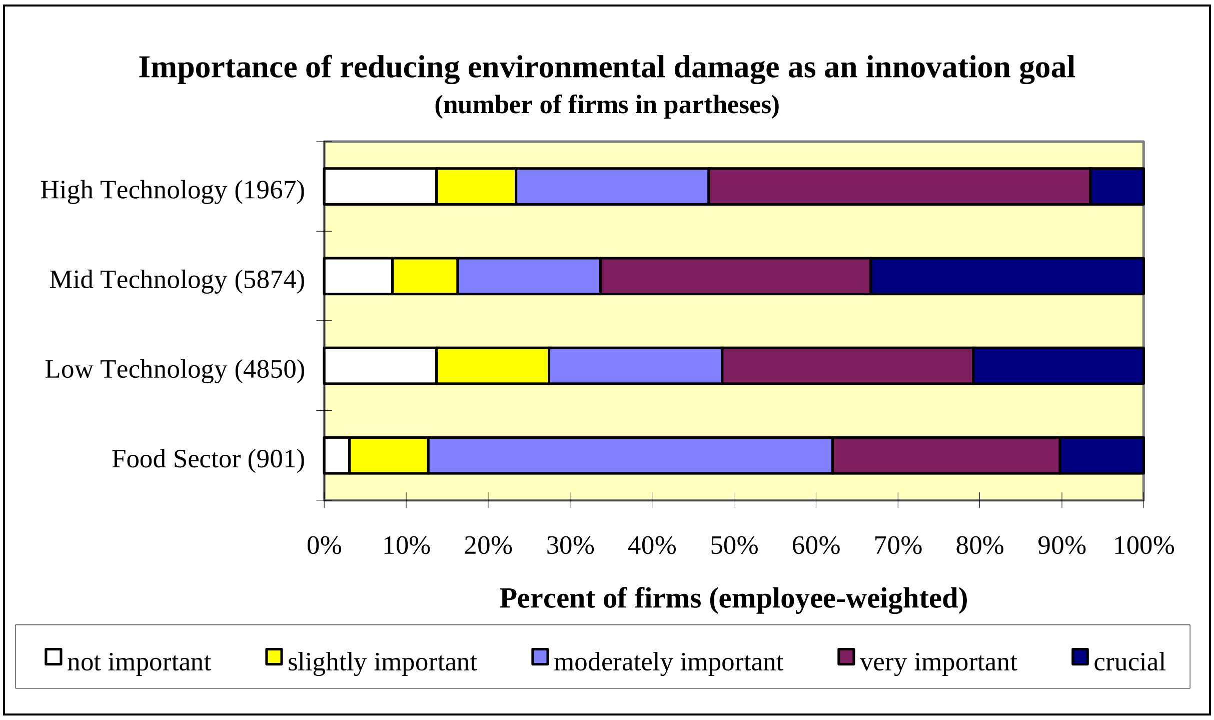

Figure 2.6

Almost half of food firms find the goal of reducing environmental damage to be ‘moderately important’. In comparison, a notably higher percentage of firms in other sectors find environmental goals to be very important or crucial. Almost half as many food firms find this goal to be not important or only slightly important compared to low technology firms. This suggests that environmental regulation is a weak driver of innovation among food processors (or the downstream end of the agro-food chain). One implication is that food processors will be less sensitive to environmental characteristics of inputs than to input costs. However, this could be changing, due to consumer pressures in a brand-conscious industry.

2.7 Conclusions

The agro-food chain contains five different levels of employment: inputs, farmers, transportation and distribution, food and industrial processing, and retail. Although employment in inputs, on the farm, and in processing has been declining since the 1970s, the agro-food chain is still a major employer in Europe. Food processing alone accounted for 9.6% of total manufacturing employment in Europe in 1992, while farm employment accounted for 1.9% to 20% of total 1997 employment, depending on the EU country.

A decline in the gross value-added of agricultural output between 1990 and 1997 of about 10% indicates that farm level employment should continue to fall, unless there is an increase in value-added or an increase in exports. To date, the decline in value-added has been met by an increase in agricultural subsidies.

Employment in the agro-food chain is likely to continue to fall in the future, due to labour-saving innovation. The analyses of the CIS data show that one of the main goals of innovation for food processing firms is to reduce both direct labour costs and the costs of materials and other inputs. The latter places pressure on input suppliers to reduce their costs, resulting in further declines in employment. The importance of cost-saving innovation strategies among food processors limits the ability of seed and PPP firms to increase their prices to cover the development costs of value-added innovations such as high lysine corn for poultry feed. If the price of this corn is too high, feed processors can simply add lysine obtained from industrial fermentation to poultry feed. This example illustrates one of the basic facts of agro-biotechnology innovation: competitive alternatives to many agro-biotechnology products will severely constrain prices (Arundel, 2001) and thereby limit the types of economically viable innovation in the seed and PPP sectors.

There are no entirely satisfactory estimates of the total number of agro-biotechnology jobs in Europe. The Ernst and Young data for 1996 predicts about 5,625 jobs among dedicated agro-biotechnology, but this underestimates total employment since it does not include jobs in large firms. In contrast, the EuropaBio estimate of 588,000 'biotechnology-dependent' jobs in the late 1990s vastly overestimates agro-biotechnology employment by reassigning many existing jobs to biotechnology. The Canadian biotechnology surveys, the best available to date, estimate that about 1% of jobs in agro-food sector involve biotechnology. A composite estimate for the late 1990s, based on several data sources, estimates about 50,000 jobs in Europe in agro-biotechnology.

Most agro-biotechnology innovations are unlikely to alter the long-term decline in employment in the agro-food chain. However, innovations based on advanced biotechnology could shift employment towards higher-skilled jobs that are traditionally better paid than low skilled jobs. An increase in activities in foreign markets is also most likely to increase European employment in R&D and management. Similarly, the Canadian biotechnology survey found that biotechnology was more likely to increase than decrease skill requirements.

3. INNOVATION STRATEGIES AND EMPLOYMENT

Current innovation strategies in the seed and PPP sectors are shifting due to technical change – primarily the application of advanced biotechnology to the development of seed varieties – and secondarily because of policy changes. This chapter provides a qualitative evaluation of the effect of these two factors on employment. The analysis is partly based on the results of interviews with managers from 13 of the 15 largest seed and PPP firms in Europe.

3.1 Main Firms in Seed and PPP Sectors

Table 3.1 lists the main seed and agrochemical firms active in Europe. The seed firms are listed in declining order, based on global sales. Monsanto, Novartis and AgrEvo are active in both seeds and plant protection products (PPPs). Interviews were conducted in all firms with the exception of DuPont.

Table 3.1 Main seed and PPP firms in Europe in 1999[1]

	Sales (m Euros)			
Firm (head office)	Seeds	PPP[2]	Employees[3]	Mergers & acquisitions
Pioneer (US)	1597	–	5,000	Purchased by DuPont in 1999.
Monsanto (US)	806	2016		Takeover by Pharmacia and Upjohn: could spin-off agriculture division.
Novartis (Ch)	706	2989	40,105	Previously created by a merger of Sandoz and Ciba-Geigy. Merged with Zeneca agrochemicals to form Syngenta.
Limagrain (F)	683		5,000	See KWS.
Advanta (Nl)	374	–	2,299	Formed from 1996 merger of

				VanderHave and Zeneca seeds.
Seminis (US)	366	–		Recent purchases of Asgrow, Royal Sluis, Petoseed, Bruinsma, Nath Sluis.
KWS (D)	331		2,000	Merged North American maize activities with Limagrain.
AgrEvo (D)	119	1,697	8,500	Formed from the merger of the agrochem divisions of Schering and Hoescht. Merged with Rhone-Poulenc to form Avensis.
Cebeco (Nl)	95		6765	
Danisco (Dk)	55		16,000	
Astra-Zeneca (UK-Sweden)		2900	34,600	Formed from merger with Astra in 1998, planned merger with Novartis.
DuPont (US)		2300	21,168	See Pioneer.
Rhone-Poulenc (F)		1991		1999 merger with AgrEvo to form Aventis.
Bayer (D)		2000	120,400	
BASF (D)		1750	105,945	Plans to acquire agrochem division of AHP (Cyanamid).

1: Most employment and sales data is for 1998. Seed and PPP sales for firms active in more than one product market is estimated from annual reports and other sources.

2: Plant protection products.

3: Worldwide employees in all business divisions.

The European seed sector also includes smaller firms, although many of them are now subsidiaries of the larger firms as a result of recent acquisitions. Unfortunately, it is not possible to estimate the total number of employees in the European seed and PPP sectors from official statistics[24]. The only realistic option is to survey the firms. The results of the survey (see Chapter Four) estimate that there are approximately 20,000 employees in the seed sector and another 20,000 in the PPP sector in six EU countries combined: the UK, France, Germany, Denmark, the Netherlands, and Spain.

3.1.1 Mergers and employment

Table 3.1 illustrates the number of mergers that have occurred among both seed and agrochemical firms in the past decade. One result is that by 1999 the top ten agrochemical firms had between 80% and 90% of the global market (DG Agriculture, 2000). The degree of concentration will increase due to planned or recently completed mergers. Concentration in the seed sector is not as high, due to the need for plant varieties that are suited to local conditions.

Several characteristics behind the development of advanced biotechnology are partly responsible for the spate of mergers in these two sectors. First, R&D in advanced biotechnology is expensive, leading firms to seek economies of scale in both R&D and marketing. Second, the technology permits synergies across seed lines, as when a valuable trait is inserted in several crop varieties. And third, the need for patent rights in advanced

[24] PPP is not an officially defined sector for economic accounts, so there are no official statistics for PPPs. Furthermore, many firms are active in several product lines, such as seeds and food ingredients (as with Danisco) or in seeds and other agricultural inputs (as with Cebeco). This makes it difficult to determine the percentage of employees that are active in the seed or PPP divisions from company reports.

biotechnology both encourages mergers in order to access patents and creates entry barriers for existing firms that might wish to expand into new product areas (OECD, 2000)[25].

The main effect of the mergers on employment is to reduce it. The creation of Novartis resulted in a loss of 1100 jobs in the agribusiness division, while DuPont cut 800 jobs world-wide in PPPs. The 1999 merger of Rhone-Poulenc and AgrEvo to form Aventis is expected to reduce employment by 3000 to 4000 jobs, with the closure of an R&D centre in the UK and a European manufacturing plant for PPPs. The loss of employment from mergers overshadows the small expected gains in R&D employment in the seeds and PPP sectors combined of about 175 jobs per year in the main EU countries (See Chapter Four).

3.2 Innovation Strategies and Employment

This section evaluates the possible employment impacts of policy changes and the technical opportunities created by advanced biotechnology.

3.2.1 Policy influences

The interviews found that environmental policies and research and technical development (RTD) policies have little impact on altering the innovation strategies of European seed and PPP firms. Environmental regulation is integrated into product development decisions, while RTD policies largely support research that is far from the market. Neither policy area appears to have much of an impact on direct employment among seed and PPP producers.

The greatest current concern is the effect of the European policy stalemate over the use of GM crops, partly reflecting public opposition to GM foods. Both could have a negative effect on employment *if* European seed firms move part of their operations overseas or if an inability to develop GM crops reduces the global competitiveness of European seed firms. However, the interview results show that conditions in Europe have not altered current innovation strategies in the seed sector, partly because of the long development time for new seed varieties of between eight and twelve years and partly because most of the firm managers are convinced that GM crops will be permitted within two to five years[26]. The one exception to this sanguine management view of the future for GM crops in Europe is the recent decline in the number of field tests of GM varieties in Europe, which peaked in 1997 (see section 3.2.2).

Farm-gate prices for agricultural crops are strongly influenced by government policies, such as the Common Agricultural Policy (CAP) in the European Union. The March 1999 Berlin agreement to reform CAP will alter the current price structure, leading farmers to shift from one crop type to another. The OECD (2000) predicts that CAP reform will increase European wheat production and decrease oilseed, maize, and coarse grain (barley, oats, etc) production. The interviews show that the seed and PPP firms pay close attention to changes in agricultural policy, because reductions or shifts in subsidies influence the market for each crop and for the PPPs used on each crop. A shift from oilseed and maize to wheat production will therefore benefit firms that provide wheat seed and PPP products for wheat, while resulting in sales losses for firms that specialize in maize and oilseed. Although individual firms could gain or lose employment, it is unlikely that crop shifts will have a detectable effect on aggregate employment in the agro-food chain.

Nevertheless, a decline in the gross level of agricultural price subsidies due to CAP reform or to world trade agreements is likely to reduce aggregate agricultural output and employment at three levels of the agro-food chain: input suppliers, on the farm, and in transport and

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[25] Patents could also be used to increase profit margins by permitting some degree of monopoly pricing. There is some evidence that firms plan to make greater use of patents. BASF intends to increase the percentage of its products under patent from 56% in 1998 to 65% in 2004.

[26] Two of the interviewed firms saw the current policy deadlock over GMOs as acting in their advantage by giving them time to build up expertise in advanced biotechnology and thereby permitting them to catch up with their competitors.

distribution. Green agricultural policies, such as to pay farmers for land stewardship, could reduce the negative effect of a reduction in price subsidies on farm level employment.

3.2.2 Technical opportunities in the seed sector

New technical opportunities created by advanced biotechnology open five possible options for innovation in plant breeding (DG Agriculture, 2000). Each option will have a different effect on employment. Table 3.2 outlines each option and its expected employment effects through the agro-food chain. The estimated employment effects assume no increase in exports and no change in current subsidy levels. Domestic demand for agricultural products is assumed to be price inelastic, except for some quality characteristics.

Table 3.2 Employment effects of innovation options in the seed sector

Option	Employment effects in the agro-food chain					
	Input supply	Farm level	Trans. & distr.	Food proc.	Industr proc.	Overall
1. Increase yield per hectare	–	↓	–	–	–	⇩
2. Increase yield per unit inputs	↓	–	–	–	–	⇩
3. Reduce risk to farmer	↑	–/⇩	–	–	–	–
4. Input switching (no change in yield)	⇧/⇩	–	–	–	–	–
5. Enhanced quality characteristics	↑/↓	⇧	↑	–/⇩	–/⇩	⇧/↑

↑ = relatively strong positive increase; ⇧ = weak increase; ↓ = strong decline; ⇩ = weak decline; –/⇩ = no effect to weak decline; – = no effect; ⇧/⇩ = substitution effects, where employment is shifted from one firm to another.

The first option of an increase in yields per hectare should result in farmers producing more at a given price, leading to a fall in crop prices (in the absence of an increase in European demand, exports, or subsidies). This should result in a decline in farm-level employment. The second option of an increase in yield per unit of inputs could have no effect on farm-level employment if yield per hectare is left unchanged, but it should decrease employment among input suppliers. An example is seed dressings or coatings of PPPs that reduce the need for wider applications of fungicides and other pesticides. This innovation should benefit the environment and reduce costs for farmers (thereby increasing farmer incomes)[27], but decrease employment among competing PPP firms.

A reduction in risk to the farmer could have no effect on total yields, but reduce the risk experienced by each individual farmer. An example is Bt cotton, which reduces the risk of crop loss from insect infestation[28]. The trade-off to the farmer is an increase in costs except when insect infestation is heavy. Over the medium-term, this could have no effect on average prices and costs. However, the extra cost of risk reducing varieties must be paid for in some manner, either through an overall increase in yields (resulting in declines in farm level employment) or through higher seed prices and lower farm incomes. Either way, this could translate into lower farm level employment.

[27] An increase in farmer incomes through higher profits per hectare could theoretically increase farm level employment by increasing the number of hectares farmed. However, this does not appear to be a realistic outcome in Europe due to subsidy structures and to the long term trend in Europe towards a decline in the number of hectares under cultivation, partly due to the demographics of an ageing population of farmers.

[28] Estimates of farmer gains for Bt maize are of an increase of 44.46 USD per acre with high infestation levels and a loss of 4.47 USD under low infestation levels (OECD, 2000, p. 102).

Input switching innovations could have no effect on farm-level employment, but it should shift employment among the input suppliers[29]. Whether or not there are environmental benefits will depend on the types of inputs that are substituted for each other. As an example, a pest resistant seed variety could reduce inputs of pesticides, resulting in a net environmental benefit and a shift in employment from PPP to seed firms.

The employment effects of each of the first four innovation options are largely confined to input suppliers and to the farm level. The final option of a change in quality characteristics could result in substantially more complex employment effects by shifting employment from one part of the agro-food chain to another. For example, a quality trait to improve the processing attributes of sugar beets would reduce costs for industrial sugar processors. This would be caused by either a reduction in other inputs (leading to a decline in employment among the firms that supply these inputs) or to a decline in labour requirements among sugar processing firms.

In addition, quality enhancement is the only option that could increase overall employment in the agro-food chain. This would occur by increasing the value-added component of agricultural products. Quality traits with industrial applications, such as the use of plant oils for lubricants or biomass for energy production, will also increase agro-food employment, although by shifting employment from industry.

Quality traits require identity preservation, or the ability to keep the improved crop separate from other varietes throughout the agro-food chain. Identity preservation will increase employment in transport and distribution. Quality traits will also require an increase in crop prices in order to cover the cost of identity preservation, which is estimated, based on US experience, to cost between 6% and 17% of the farm-gate price, depending on the crop (DG Agriculture, 2000). Farm level employment could also increase slightly if the price paid for improved crops increases and if farmers can capture part of the price increase.

One estimate is that the percentage of US crops that follow an identity preservation system will increase from 8% to 10% today (largely for certified seed and organic crops) to 25% to 30% by 2005 (DG Agriculture, 2000). This appears over optimistic for Europe, as a major shift by seed firms towards quality traits will not show up on the seed market for at least two to five years (see section 3.3.2)[30].

One aspect of quality traits will have a net positive effect on European employment. This is when domestic European production replaces imports. An example is high lauric acid rapeseed which could replace imported coconut and palm oil in lubricants and detergents (OECD, 2000). Another example, although a step removed from traditional agriculture, is genetically-engineering bacteria to produce natural vanilla and other aromatic botanicals that are currently imported (Acharya, 1997).

Improved quality traits for animal feed could have substantial environmental benefits because of the size of animal husbandry in agricultural output. Developments such as low phytate maize could have strong environmental benefits by reducing water pollution, but the cost savings for the animal farmer will be very low. The problem is that low phytate maize will need to cost more than other maize varieties because of development costs and the need for identity preservation. The animal farmer is unlikely to pay the extra costs without an economic incentive, either via tax incentives, or pollution taxes on other maize varieties.

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[29] There is little conclusive evidence so far that HT crops have increased farm incomes in the United States (DG Agriculture, 2000; OECD, 2000), so such input switching is unlikely to lead to increased farm-level employment. However, there is good evidence for input switching. GM RoundUp ready soybeans have significantly reduced the American market for other herbicides. This has shifted employment from competing herbicide manufacturers to Monsanto. The use of imazetaphyr declined from 44% of US soybean acres in 1995 to 17% in 1998. Roundup use increased from 10% of acres in 1990 to 45% in 1998 (DG Agriculture, 2000).

[30] This could also be an optimistic estimate for the US. In 1999, GM crops with quality traits accounted for only 50,000 hectares in Canada and the United States, out of a total of 41.5 milllion hectares planted with GM crops in these two countries. The quality crop is high oleic oilseeds (DG Agriculture, 2000).

Other quality traits, such as feed that is better matched to the nutritional requirements of specific species, could reduce input costs for animal farmers. The employment effect would be neutral for the animal farmer but negative for farmers that grow animal feed, due to a decline in demand.

Potential GM crops in Europe

Another important influence on the employment effects of various innovation options is the share of specific crops in total crop values and cultivated hectares in Europe. This particularly applies to the main European crops that have been the target of genetic engineering: maize, sugar beets, and oilseeds, followed by potatoes. As shown in Table 3.3, the main GM target crops for Europe account for only 16.3% of the total crop value in 1997 and for 10.1% of the total hectares under cultivation[31]. The effect of GM crops on employment in the agro-food chain is likely to be comparatively small until GM techniques can be applied to other cereals (accounting for 16.3% of the crop value) and to vegetables, fruits, and vines. The latter account for a little over half of the total crop value, but many of these crops have very small individual markets.

Table 3.3 EU 15 crop values and hectares under cultivation

	1997 crop values (Million Ecus)		1997 hectares under cultivation (000)	
Main potential GMO crops	17,110	16.3%	13,617	10.1%
Maize	*4,128*	*3.9%*	*4,387*	
Potatoes	4,227	4.0%	1,539	
Sugar beets	5,657	5.4%	2,041	
Oilseeds	3,098	3.0%	5,650	
Cereals (excl. maize)[1]	17,143	16.3%		
Vegetables, fruits, and vine crops[2]	55,110	52.5%		
Other crops	15,567	14.8%		
Total	**104,930**	**100.0%**	**134,631**	**100.0%**

Sources: OECD (1999), DG Agriculture (2000b).

1: Wheat accounts for 10,762 m Ecus and barley for 4,128 m Ecus.

2: Vegetables account for 19,466 m Ecus, fruits (including tree fruits and olives) for 21,820 m Ecus, and vineyard products for 13,824 m Ecus.

The employment effect of advanced biotechnology in the medium-term (over the next five to ten years) will depend on the ability of seed firms to apply genetic engineering to crops with increasingly smaller markets. This will depend on the cost of using GM techniques. As with many other technologies, these costs should fall over time.

3.2.3 Technical opportunities in the PPP sector

Three main innovation options are available for the development of plant protection products, as illustrated in Table 3.3. The first option forms the status quo. The long term trend is towards stronger regulation to reduce environmental and health risks. This could reduce aggregate employment if total pesticide use falls, but PPP firms may be able to counteract this trend by developing new pesticides that are less environmentally toxic. Environmental regulation that encourages their use, combined with patent protection, would permit the

[31] Crop values exclude meat and dairy production, although the value of crops used as animal feed is included. The total hectare under cultivation for the main GM crops is also relatively low because the total cultivated area also includes pasture land.

manufacturer to charge a premium price. Chemical pesticides must also compete against other alternatives, such as pest resistant crop varieties, bio-pesticides, and IPM.

The second option is a relatively recent development and includes herbicide tolerant crops in which the pesticide and the crop seed are sold together as a package. This option competes against alternatives such as IPM or non-pest resistant crops combined with pesticides. A new development is seeds that are genetically engineered to respond to chemical switches that can turn on or off selected traits, as needed. In the future, crop-PPP packages could be linked to higher value-added crops based on quality traits.

Table 3.3 Employment effects of innovation options in the PPP sector

Option	Employment effects					
	Input suppl	Farm level	Trans. & distr.	Food proc.	Industr proc.	Overall
1. Chemical pesticides	⇧/⇩	–	–	–	–	–/⇩
2. Chemical-seed combinations	🡅/⇩	–	–	–	–	⇧
3. Bio-pesticides	⇧/⇩	–	–	–	–	–

🡅 = relatively strong positive increase; ⇧ = weak increase; 🡇 = strong decline; ⇩ = weak decline; –/⇩ = no effect to weak decline; – = no effect; ⇧/⇩ = substitution effects, where employment is shifted from one firm to another.

The third option of bio-pesticides forms only a very minor part of the innovative activities of agro-chemical firms (See Chapter Four). It competes with the other two options.

3.3 Innovation strategies of Seed and PPP firms

The preceding section outlines the possible employment effects of several innovation options available to seed and PPP firms. This section draws on the results of the interviews and on an analysis of the GMO field release data to determine these firm's current innovation strategies.

3.3.1 Seed firms

Two shifts in innovation options have occurred in seed firms. First, during the 1990s, firms shifted from a focus on increasing yield to improving characteristics such as pest resistance. This choice could have shifted some employment from PPP firms to seed firms. Second, future innovation strategies are expected increasingly to stress high-value quality characteristics[32], which is the only option that could have net positive employment effects on the agro-food chain. An increase in quality traits is also predicted in published statements. Both Monsanto's Chief Executive Officer, Robert Shapiro, and Cargill Agricultural Division President, Fritz Corrigan, predicted that within a decade a quarter of all grain production will be devoted to quality traits (Morrison and Giovannetti, 1999). A shift to quality traits will also increase the influence of processors and retailers on the choice of crops, with farmers increasingly growing crops under contract.

[32] Examples include the following: Advanta is working on higher sugar content in beets and inuline in chicory; BASF on drought and cold tolerance, extraction of polyunsaturated fats, and vitamin enrichment; Pioneer on low phytate corn, high oleic sunflowers, high oil maize and soybeans; KWS on the processing quality of sugar beets; Monsanto has six quality traits in the pipeline, four of which are for animal feed and two for food processing; and Astra-Zeneca is working on cereal nutrition, vitamins, oil content, processing, sweeteners, low phytate animal feed, and feed nutritionally tailored to specific animal species. Limagrain, Novartis, AgrEvo, Bayer and Seminis all mention a shift to quality traits without giving specific details. Nevertheless, several firms note that most of their research is still on agronomic traits, including Rhone-Poulenc, Monsanto, Seminis, and BASF.

The shift in both innovation strategies, from yield to pest resistance and to quality traits, is not entirely due to genetic engineering, since five of the ten main seed firms continue to stress the use of conventional breeding technology or conventional techniques combined with markers (developed through advanced biotechnology). Seminis, for example, estimates that only 0.2% of its global sales in 1999 were from GMOs, while Advanta starts with conventional techniques and only used genetic engineering if a desired trait cannot be obtained through conventional breeding. (The use of specific breeding technologies is examined in greater detail in Chapter Four.) The main driver for past shifts in innovation options could be a search for more profitable seed markets, independently of the development of advanced biotechnology.

Another trend among the seed firms is to concentrate their breeding activities among their core crops, or on the major industrial crops such as maize, grains, and oilseeds where large market sizes increase the potential profits and provide a greater chance of recouping development costs[33]. As an example, Cebeco ceased its breeding programme for rapeseed in order to concentrate on its core crops. This trend is part of a general globalisation of the seed sector, but sucess in this strategy depends on the ability to insert high value-added traits into elite varieties that are adapted to local conditions in Europe, North America, Latin America, and Asia. This will drive seed firms to master several technical options: high throughput genetic screening to identify valuable traits, genetic engineering to insert these traits into many different varieties, and the use of marker and other technologies to reduce the time required to develop plant varieties.

Given the need to develop local varieties *in situ*, seed firms will need to develop a global presence based on acquisitions, greenfield investments, or cooperation agreements. The positive employment effects among European-owned firms is likely to be limited to high-skilled jobs in management, administration and research.

3.3.2 Evidence for a shift towards quality traits

The qualitative assessment of employment effects in section 3.2 above shows that the only innovation option that is likely to have a positive impact on aggregate employment in the agro-food chain is a shift to higher value-added quality traits. The interviews and published statements from seed firms show that many of the seed firms are moving in this direction. This raises the question: when are market-ready quality traits likely to be available? And, what percentage of the innovative effort of seed firms are going into quality traits?

A partial answer to both questions can be obtained from analysing the European field release data for GMOs. Under part B of Directive 90/220/EEC, any organization wishing to conduct an outdoor field trial of a GMO within any of the 15 EU member states must first notify the relevant government authority in the state where the field trial is to take place. The Joint Research Council (JRC) of the European Commission collects the national field test data and provides it on-line as the Summary Notification Information Format (SNIF).

Field trials can begin two to three years after the start of a project to develop a new variety and run almost until the variety is ready for commercialisation. The total time required is between 8 and 12 years, depending on the firm and the plant variety[34]. Therefore, the lag time between the first field trials and market-readiness is probably around seven years. Since some field trials will take place shortly before market-readiness, the field trial data provide an indicator of what is likely to come onto the market within the next two to seven years. Changes in the number of field trials, and the percentage of all trials for specific types of

[33] One possible environmental effect of this development is a decline in the diversity of the types of crops that are grown.

[34] Some plant varieties can take up to 15, but the interview results show that the best estimate for most firms is between 10 and 12 years. A firm does not need to notify greenhouse trials, which means that the lag time for outdoor trials of crops that can be grown in greenhouses will be shorter than for other crops.

traits, can also be used to identify shifts in innovation strategies and the percentage of innovative effort expended on different types of GM traits.

The SNIF data contains four variables: the common name of the plant, such as ‘cauliflower’ or ‘maize’, the genetically-modified trait applied to the plant, such as ‘glufosinate tolerance’, the name of the organisation running the field trial, and the notification number, which includes information on the country where the field trial is to take place and the date of application.

For this study, records were abstracted from all SNIF applications filed between 1990 and July, 2000. The traits were aggregated into five major categories: herbicide tolerance (HT), male sterility, pest resistance, quality traits (including industrial crop applications) and yield. Industrial traits can increase employment in the agro-food chain when crops are used to replace other sources of industrial inputs. The total number of field trials reached a peak in 1996 and 1997, with 369 and 363 trials respectively. In 1998 the number of trials fell to 304 and to 285 in 1999. The data for 2000 is incomplete.

Figure 3.1 gives the total number of field trials for each trait between 1990 and mid 1999. Figure 3.2 gives the percentage of all trial-trait combinations that are for each of the five trait classes. A two-year running average is used to smooth out annual differences and indicates the percentage of firm investment in each trait category. Figure 3.2 shows that over 40% of all field trials during the 1990s were for herbicide tolerance, followed by pesticide resistance, which accounts for about 30% of all trials for most years. The share of quality traits increased between 1991 and 1997, but has remained relatively stable since then, at about 20% of all trials. There has been a marked decline in share of tests of male sterility, while yield characteristics account for less than 5% of trials in all years[35].

[35] The low investment in yield traits could be due to the technical difficulty in making major improvements in current yields (Ruttan, 1999). For example, introducing nitrogen fixation in cereals such as corn, rice and wheat has proven to be far more difficult than originally thought in the early 1980s.

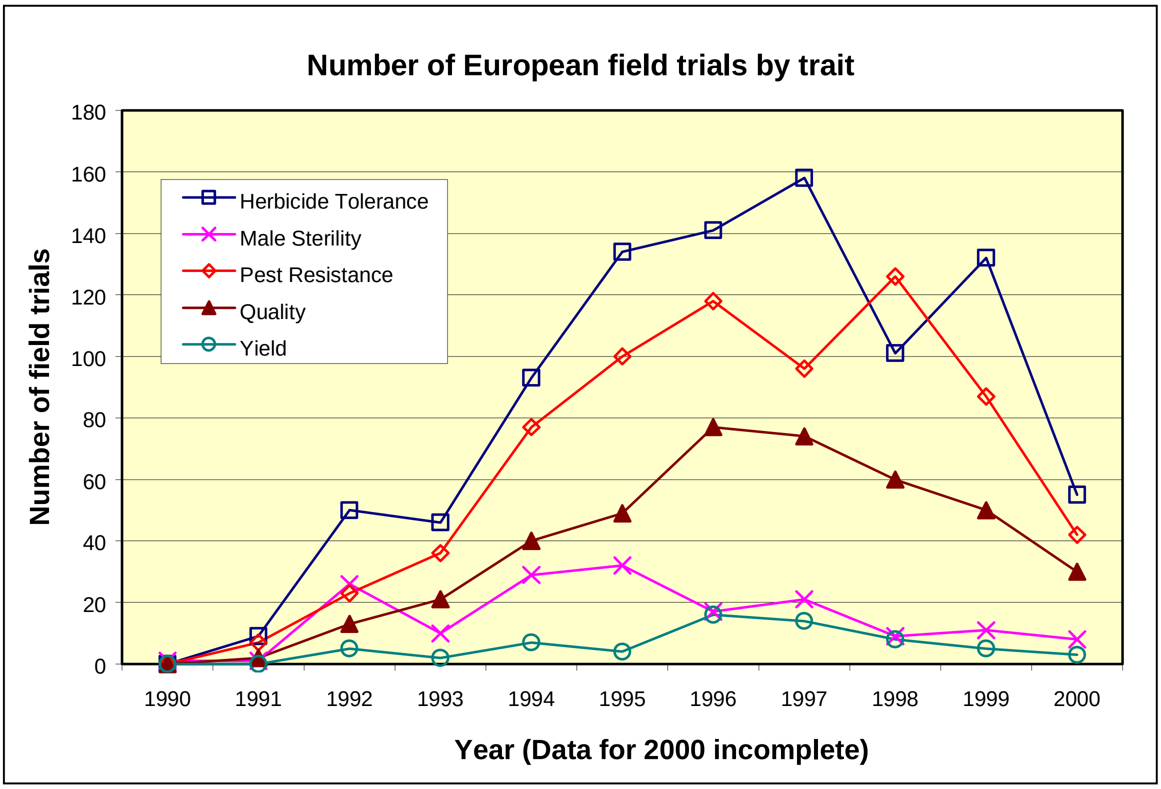

Figure 3.1

Overall, the analyses of the field test data provide little support for a major shift in the near future in the types of GM crops that are likely to come onto the market, since the relative share of each type of trait has been stable over the past four years. Furthermore, quality traits account for only 20% of the field tests, with input switching traits such as HT and pest resistance accounting for 70% of the trials. It is possible that most of the research on quality traits has not yet reached the field trial stage and therefore has not shown up in the SNIF data. If true, this indicates that a shift to marketing higher value-added quality traits is probably over five years away, which also means that any positive employment effects are equally distant in time.

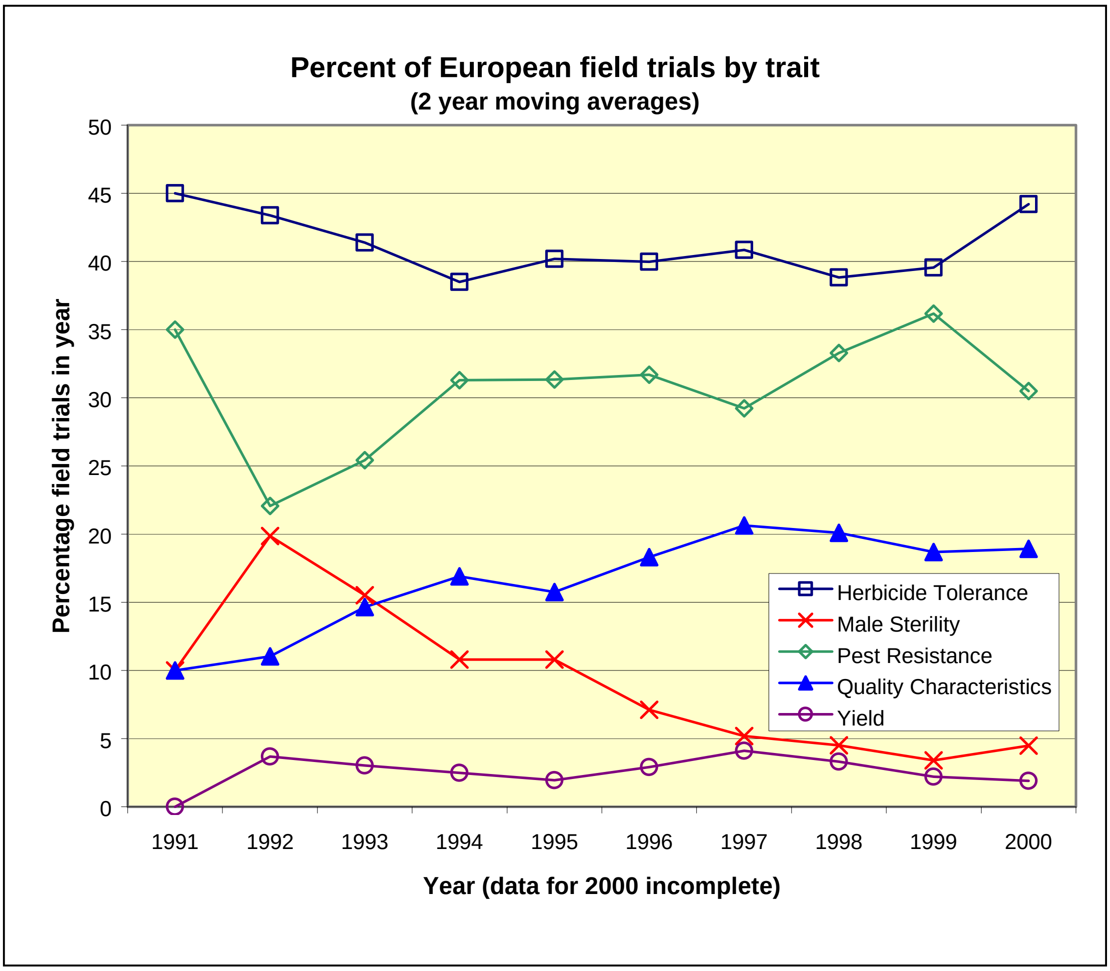

Figure 3.2

3.3.3 PPP firms

The main shift in the innovation strategies of these firms has been to reduce their product portfolios by concentrating on a limited number of products for crops with large markets. A large market is needed to be able to cover the development costs for new PPPs. Astra-Zeneca plans to reduce its portfolio of PPPs from 40 products in 1994 to 12 products in 2003. One result of the increasing focus on a limited range of PPPs for large market crops is that there will be fewer firms working on PPPs for small market crops such as some fruits and vegetables[36].

A second shift is towards PPP-seed combinations, as noted above, although the survey results given in Chapter Four show that only a minority of investment by PPP firms is in this direction. The interviews showed that PPP firms expect a general shift towards higher value added quality traits (as promised by the seed firms) will lead farmers to pay more for PPPs in order to protect their more valuable crops. Therefore, some of the aggregate increase in

[36] The increasing concentration by both seed and PPP firms on a limited number of main crops is ironic given the stated goal of many of these firms to 'feed the world'. More accurately, the world needs to *eat* the same crops.

employment in the agro-food chain due to higher-value added crops could spill-over into increased employment among PPP firms.

3.4 Conclusions

The employment effects of innovation in the seed and PPP sectors are minor compared to other major influences on employment in the agro-food chain such as a long-term decline in employment from increasing productivity and labour-saving innovation (see Chapter Two), mergers that result in job losses, and a European commitment to decrease agricultural subsidies.

Five different innovation options are available to seed firms: increase yields, increase yield per unit of inputs, reduce risks, switch inputs, and enhance quality characteristics. With one exception, all innovation options in the seed sector are likely to result in aggregate job losses across the agro-food chain, although there could be direct employment increases among individual firms from substitution effects. The exception is improved quality traits for food and industrial crops, which could increase aggregate employment in the agro-food chain. This is partly due to the costs of identity preservation and partly to higher value-added crops. Quality traits that permit European production to replace imports will also increase European employment.

The potential for positive employment effects from improved quality traits faces an upper limit, due to competition from alternatives to value-added crops. Some quality traits with environmental benefits, such as phytase reduced feed crops for animals, are unlikely to be competitive without some form of environmental subsidy.

In the short term (up to five years), advanced biotechnology will only have a minor impact on European employment. This is because only 16% of European crop values are from the main GM crops, which limits the potential job impacts of GMOs. Furthermore, both the analysis of the field test data and the interview results show that major developments in quality traits are at least five years away from the market.

The innovation options available to PPP firms will likely result in declining employment, with the exception of crop/PPP combinations. Conversely, a trend to higher value-added crops could partially counteract a decline in PPP employment. Most PPP firm managers believe that European demand for PPPs will remain stable or increase slightly because farmers will invest more in PPPs in order to protect higher value-added crops. Stable demand in Europe, however, will not be enough to counteract the long term decline in manufacturing employment in agrochemicals.

The global competitiveness of European seed and PPP firms is an increasingly important factor in their ability to maintain or increase European employment levels. The high cost of developing GM crops and PPPs that can meet tougher environmental regulations requires large product markets, given strong price competition in the agro-food chain. The need for large markets is partly behind the globalisation of these two sectors, with firms looking for new markets in North America, Latin America, and Asia. Firms have sought to increase their global competitiveness through mergers and by limiting their product portfolio to a smaller number of products with large current or potential markets. For European seed firms, most of a possible increase in employment due to globalisation is likely to take place in high skilled management, administration and research positions. The actual field testing and growing of seed will take place closer to foreign markets. PPP firms, in contrast, could continue to serve export markets from both European and foreign manufacturing plants.

4. SURVEY OF SEED AND PPP FIRMS

The technologies used to develop new seed varieties and plant protection products (PPPs) were investigated in two surveys of firms in six EU countries: the UK, France, Germany, the Netherlands, Denmark, and Spain. The primary goal of each survey was to estimate current and expected employment levels by the type of technology in use. This required collecting data on the distribution of current and expected development budgets.

Three technologies are available for seed firms to develop new agricultural crop varieties. The most advanced option is the use of genetic engineering, commonly referred to as agricultural biotechnology. The second option is assisted conventional breeding which uses some of the techniques developed for genetic engineering, such as DNA markers and gene sequencing, to reduce the time required to develop new varieties. The third option is conventional or classical plant breeding.

Three main options are also available for developing PPPs: chemical pesticides, bio-pesticides, and chemical/crop combinations. The latter option requires combining seed and pesticide expertise.

The investment choices of European seed firms in these three technologies are likely to be influenced by a wide range of factors, such as their cost, in-house technical expertise, the regulatory environment, and the potential market for agricultural crops. Neither the regulatory environment nor the market, in comparison with other countries such as the United States and Canada, are currently favourable towards genetically-engineered crops. This raises the possibility that the competitiveness of European seed firms, in comparison with their American competitors, could suffer if genetic engineering develops into the most profitable method for developing new plant varieties.

4.1 Methodology

One-page questionnaires were faxed to all seed and pesticide firms that met three criteria:

1. Location within one of six EU countries: the UK, Spain, France, Germany, the Netherlands and Denmark.
2. Manufacture or develop pesticides or produce seeds within the country where the firm is located.
3. Commercial organisation from the private sector.

Foreign-owned subsidiaries were included as long as they conducted relevant activities within the country of location. The second criteria excluded firms that only distributed pesticides or seeds, while the third criteria excluded public organisations such as universities, agricultural colleges and publicly-funded research organisations. All identified seed or pesticide firms were included in the survey, but firms that did not develop seeds or pesticides were excluded once more information on their activities was obtained from the questionnaire or from telephone follow-up calls.

The population of firms to survey in each country was identified from a range of sources, including the Internet, contacts within each country, trade associations, government sources, and telephone calls to the firms. The survey was sent to an identified contact person, preferably an R&D manager, but a CEO or Managing Director was chosen for firms that did not have an R&D manager. The names of contact personnel were identified, if available, from annual reports or other published information. Alternatively, this information was obtained from preliminary telephone calls to the firms[37].

[37] It was not possible to obtain a contact name for some firms, even after repeated telephone calls. For these firms, the questionnaires were faxed to the R&D department, CEO, the department suggested by the firm, or just to the firm itself.

The survey ran between early May and July of 1999, using staggered start dates for different countries. The fax and follow-up protocol is given in Table 1 of Appendix III.

The unit of observation for both surveys is the domestic operations of the respondents' firms only. The respondent was asked to exclude data for subsidiaries or parent firms located outside of their country of location.

4.1.1 Survey response rates

The seeds and pesticide questionnaires were designed to maximise both the survey response rate and the item response rate (response rate for each question by respondent firms). These two goals placed limits on the length and type of questions[38]. Both questionnaires are only one page in length and avoid asking for confidential information or for information that the respondent might find difficult to provide. Spanish, French, Danish, Dutch, English and German versions of the questionnaires were used in the national surveys, as required. Appendix III provides English versions of both questionnaires.

The adjusted response rate is 72% for both surveys. Table 4.1 provides basic survey response rates. By country, the response rates varied from 53% to 86% for the pesticide survey and from 70% to 81% for the seeds survey. In total, 56 responses were obtained from firms that develop pesticides and 99 responses from firms that develop seeds.

Table 4.1 Survey response rates for pesticides and seeds questionnaires

	Pesticides	Seeds
Total questionnaires sent out	140	220
Total returns	101	158
Of which:		
Fails basic eligibility requirements[1]	7	25
No development work[2]	38	34
Valid responses (firm meets development requirements)	56	99
Adjusted response rate[3]	72%	72%

1: Reasons include: out of business, public institution, not active in pesticides or seeds (as applicable), repeat questionnaire to same firm.

2: Firm does not develop new or improved pesticides or seeds, although it can, as relevant, manufacture pesticides or produce or field test seeds developed outside of its location.

3: Assumes that the percentage of firms that do not meet the eligibility requirements are the same among the non-respondents (39 pesticide firms, 62 seed firms) as among the respondent firms.

The response rates to each question are given in Table 4.2, limited to firms that develop new seeds or pesticides. The very high item response rate of 99% for the question on the distribution of the development budget shows that the format of this question was easily understood by the respondents and that it did not raise concerns over confidentiality. In contrast, the item response rate drops to 83.8% for the seeds questionnaire for the question on world-wide sales and to 71% for the sales location for pesticide firms. Part of the reason for the drop in these item response rates could have been concern over confidentiality, or the respondent may not have known the answer.

[38] In order to maximise the item response rate, the key question on the distribution of the development budget by technology (for seeds) or by product (for pesticides) in 1999 and 2002 does not ask for exact expenditure data but for a percentage distribution of total spending across three categories. The reason for this is that the respondents are likely to view actual expenditures as confidential and to find it more difficult to provide expenditure amounts than percentages.

Although an attempt was made to collect information on firm size from non-respondent firms during the telephone follow-up calls, data on employment was only obtained from 16% of these firms. This is not enough to permit a comparison of firm size between respondent and non-respondent firms. Alternatively, the response rates for major multinational firms, including relevant divisions and subsidiaries, were compared to the response rates for all other firms. In total, 50 questionnaires were sent to the relevant divisions of 11 major multinational seed firms and 39 questionnaires were sent to the relevant divisions of 10 major multinational pesticide firms. The responses rate for the major pesticide firms is almost identical to the response rate for other pesticide firms. In contrast, the response rate for the major seed firms is 5.6 percentage points less than the response rate for other seed firms. This means that the results for the seeds survey are slightly biased towards the secondary firms, which are smaller, on average, than the major multinational firms[39].

Table 4.2 Item response rates (in percent) for 99 firms that develop seeds and 56 firms that develop pesticides

Question or question group	Seeds	Pesticides
Use of three development technologies	100.0	–
Development of three pesticides	–	100.0
Distribution of development budget	99.0	98.2
Total number of employees in country of location	92.0	89.3
Number of employees involved in development work	100.0	96.4
Change in the number of development employees in three years	96.0	94.6
World-wide sales from production in the country of location	83.8	85.7
Percentage of sales in EU countries[1]	84.7	71.1
Percentage of sales in non-EU countries[1]	83.5	71.1

1: Excludes 14 seeds and 11 pesticides firms with zero sales.

4.1.2 Imputed values for employment and sales

The major goal of both surveys is to estimate investment in different types of technology and to estimate current and future employment. In both cases, the results must be weighted by a measure of firm size, such as the number of employees, because the distribution of both seeds and pesticides firms by the number of employees is highly skewed. However, 8% of respondent firms that develop seed varieties and 11% of respondent firms that develop pesticides did not answer the question on employment. The number of employees for these firms was imputed, using linear regression techniques. Imputation was also used to estimate sales in order to improve the use of sales-weighting in an analysis of export rates and to calculate the average sales per development employee.

The question on future employment is limited to employees active in development, rather than asking about the expected change in total employment. Although information on changes in total employment would have been of value, R&D managers (the majority of respondents) would probably be less likely to be able to predict changes in total employment than changes in the number of research employees. This should not pose serious problems because the total number of employees and the number of employees active in development are correlated, with an adjusted R^2 coefficient of 0.5 ($p = 0.000$) for seeds and 0.9 ($p = 0.000$) for pesticide firms. Furthermore, the development of improved seeds or pesticides will

[39] The telephone follow-ups for the Netherlands, Germany and the UK obtained a reason for the non-response from 22 of the 54 non-respondent seeds and pesticides firms in these three countries. The most common response was a lack of time (32%), followed by the "questionnaire was passed to someone else in the firm" (23%). Only two respondents cited confidentiality concerns (9%) and three gave company policy as a reason (14%).

provide the foundation for all future employment growth and productivity gains. For this reason, focusing on employees active in development tasks should provide a measure of future economic expectations.

4.2 Results of the Survey of Seeds Firms

A minimum estimate is that the seeds survey provides coverage of half of all EU investment in agricultural genetic engineering, due to a response rate of 72% and the fact that the six European countries covered in the survey accounted for 70.7% of all field tests of genetically modified organisms (GMOs) within the EU between January 1997 and July 23, 1999[40]. The actual coverage is likely to be higher, since a large share of Italian field trials (16% of the total) are the work of firms based in other EU countries.

Table 4.3 provides, by country, the total number of responding firms that are active in the seeds industry, the number of these firms that develop new seed varieties, and the number of employees among the latter group of firms. The results show that the majority of firms that develop new seeds are from France and the Netherlands. These two countries account for 51.5% of the responding firms and 63.3% of the total number of employees. In contrast, Spain provides 21.2% of the responding firms but only 8.3% of the total number of employees, largely because many of the firms in Spain are small or subsidiaries of foreign firms.

Table 4.3 Number of responses by country for seed firms

Country	Number of firms active in seeds	Firms that develop seeds			
		Number of firms	Percent of total firms	Number of employees[1]	Percent total employees
UK	14	13	*13.1*	1286	9.4
France	26	21	*21.2*	4498	32.7
Germany	23	10	*10.1*	1837	13.4
Netherlands	34	30	*30.3*	4206	30.6
Denmark	7	4	*4.0*	780	5.9
Spain	29	21	*21.2*	1139	8.3
Total	*133*	*99*	*100%*	*13,746*	*100%*

1: Limited to seed employees in the country (excludes employees in foreign subsidiaries).

In total, there are an additional 2,583 employees among the 34 seed firms that do not develop new seed varieties. Eighteen of these firms market varieties developed outside of their country of location, while development work in the remaining 16 firms is limited to field testing. All remaining results given below are limited to the 99 firms that develop new seed varieties.

4.2.1 Technology used to develop new seed varieties

All 99 firms that develop new seed varieties are classified into three technology classes, based on the most advanced technology that they use to develop new seeds. The number of firms that use each technology in 1999 and which plan to use each technology in 2002 are given in Table 4.4. For example, the first row of Table 4.4 gives the percentage of firms that use genetic engineering. These firms can *also* use assisted conventional or conventional

[40] Based on an analysis of the European SNIF data (see section 3.3.1.1).

plant breeding techniques. The second row gives the percentage of firms that use conventional breeding methods assisted by more advanced biotechnology such as DNA markers or sequencing. These firms can also use conventional breeding. The third row gives the percentage that *only* use conventional plant breeding technology.

Table 4.4 Current and planned users of each seed development technology

Most advanced	Current use (1999)			Planned use (2002)		
technology in use	N	% firms	% employees	N[1]	% firms	% employees
Genetic engineering	33	33.3	68.4	48	49.0	79.5
Assisted conventional	23	23.2	18.1	30	30.6	14.0
Only conventional	43	43.4	13.5	20	20.4	6.5
Total	*99*	*100%*	*100%*	*98*	*100%*	*100%*

1: One firm did not provide data on planned use.

The results in Table 4.4 show that 33 firms currently use genetic engineering to develop agricultural seed and plant varieties[41]. A comparison of the 1999 and 2002 data show that the seed firms plan to shift their development budget to more advanced technology, with the percentage of firms using assisted conventional breeding increasing from 23.2% in 1999 to 30.6% in 2002 and the percentage of firms using genetic engineering increasing from 33.3% to 49%.

The employment-weighted results in Table 4.4 show that the use of genetic engineering is concentrated among large firms. Although only a third of firms currently use genetic engineering, they account for 68.4% of total employment. This is because 66% of firms with more than 100 employees use genetic engineering, compared to only 19% of firms with between 35 and 99 employees and 17% of firms with less than 35 employees[42].

The results in Table 4.4 show whether or not a firm makes *any* use of each developmental technology. Table 4.5 goes a step further by giving the employment-weighted share of development budgets allotted to the three development technologies for 1999 and the expected share for 2002[43]. We assume that employment-weighting provides a reasonable approximation to the distribution of total investment in the development of improved agricultural seed and plant varieties[44].

[41] For comparison, Ernst and Young (1998) estimated that there were 58 European firms with less than 500 employees that were active in either agricultural biotechnology (ag-bio) or food processing in 1997. Unfortunately, the Ernst and Young data does not separate ag-bio firms from food processing firms, but the former probably account for at least 80% of the total, or 46 firms. Of these, 70% (based on the SNIF data) are probably based in the six countries included in this survey, leaving 32 ag-bio firms. Some of the Ernst and Young firms could also be included in the 23 firms that use assisted conventional breeding. Of the 33 firms in the PITA survey that use genetic engineering, 29 have less than 500 employees, which is comparable to a rough estimate drawn from the Ernst and Young data.

[42] Of the 33 firms using genetic engineering, 66% have more than 100 employees, 16% have between 35 and 99 employees, and 19% have less than 35 employees. For full results on current technology use by size class, see Table 2 of Appendix III.

[43] Weighting by sales or R&D employees produces almost identical results.

[44] This is a reasonable assumption, given a high correlation between employee counts and R&D investment in most survey research on innovation.

Although 68.4% of employees worked for a firm that used genetic engineering in 1999, Table 4.5 shows that the vast majority of the development budget, 89.8%, did *not* involve genetic engineering. Instead, conventional breeding techniques accounts for an estimated 73.4% of 1999 development budgets. In addition, the largest expected growth in three years is in the use of assisted conventional breeding, which is estimated to increase 59% from 16.5% of current investment to 26.2%, while genetic engineering will increase 44% from 10.2% to 14.7%. However, since assisted conventional technology requires the ability to use several technologies developed for genetic engineering, this implies that 41% of investment by 2002 will involve the use of some advanced technology. It is also possible that some of this investment could be switched to genetic engineering given favourable regulatory, market, and technical conditions for genetically-engineered crops[45].

Table 4.5 tribution of current and expected crop development budgets by seed development technology (Employment weighted)

Most advanced technology in use	1999	2002	% Change
Genetic engineering	10.2%	14.7%	+44%
Assisted conventional plant breeding[1]	16.5%	26.2%	+59%
Conventional plant breeding	73.4%	59.1%	-19%
	100%	100%	

1: DNA mrkers, gene sequencing, gene amplification, etc.

Furthermore, the results do not necessarily reflect the use of genetic engineering in the development of new seed varieties, since some of the expenditures on conventional plant breeding would have been used to test the stability of genetically-engineered seed varieties. In contrast, almost all of the spending on assisted conventional breeding would have been used to develop new plant varieties. A maximum estimate of the share of genetic engineering in developing, rather than testing, new varieties can be obtained by assuming that only the two most advanced techniques are used to develop new seeds. Under this assumption, 38% of the 1999 budget for developing new seeds could have used genetic engineering [10.2/(10.2+16.5)*100]. Of course, the actual share of genetic engineering in the development of new varieties is likely to be less than this maximum estimate, since many plant varieties are still developed through conventional breeding techniques.

There are only minor differences by firm size class in the share of the current development budget that is spent on genetic engineering. The employment weighted share is 14% among firms with fewer than 35 employees, 7% among firms with between 35 and 99 employees, and 10.5% among firms with more than 100 employees. The difference by firm size in the expected share in three years diminishes further because a higher percentage of mid-sized firms that do not use genetic engineering in 1999 plan to adopt this technology by 2002.

Table 4.6 provides an alternative method of evaluating changes in the crop development budget. It gives the percentage of firms with and without employee-weighting that expect to decrease, increase, or leave unchanged the percentage of their development budget expended on each of the three technologies. These results confirm the general shift out of conventional breeding technology in favour of the two advanced technologies. For example, the employee-weighted results for all firms combined show that 81% of firms expect to decrease their investment in conventional biotechnology while only 3% plan to increase

[45] The distribution of the total 1999 research budget allotted to genetic engineering varies considerably by country: 1% in Spain, 6% in Germany, 8% in France, 8% in the Netherlands, 13% in Denmark, and 36% in the UK. The largest expected increase in the fraction of the development budget that will be allotted to genetic engineering in 2002 is in Spain and Germany, which have the lowest current share. Genetic engineering is expected to receive 6% of the Spanish development budget in 2002 (a 600% increase) and 20% in Germany (a 333% increase), compared to increases of about 50% for France, the Netherlands and Denmark. In contrast, the share of genetic engineering is expected to fall about 8% in the UK to 33% in 2002.

investment in this technology. In contrast, 61% of employee-weighted firms plan to increase their investments in genetic engineering and 76% plan to increase investments in assisted conventional breeding.

Table 4.6 Percentage of firms that plan to decrease, leave unchanged, or increase the percentage of their crop development budget spent on each developmental technology

Developmental Technology	Direction of change: Decrease		No change		Increase	
	Firms	Employees	Firms	Employees	Firms	Employees
Genetic engineering	3%	5%	62%	35%	35%	61%
Assisted conventional	4%	5%	34%	19%	62%	76%
Conventional	65%	81%	34%	15%	1%	3%

The weighted results provide a measure of total investment spending, which is the best measure of the future number of new crop varieties developed using different technologies. Conversely, the unweighted results possibly provide a better measure of the influence of opportunities on investment decisions. For example, concern over opposition to genetically-engineered crops should be visible in the investment decisions of individual firms. Of note, almost twice as many firms plan to increase investment in assisted conventional technology (62%) as in genetic engineering (35%). This could reflect concerns about the market for genetically-engineered crops, difficulties in adopting advanced technology, or both.

The results in Table 4.6 were also calculated separately by technology class (see Table 3 in Appendix III). Planned investment in genetic engineering is higher among current users than non-users of this technology, possibly reflecting barriers to adoption for current non-users. Only 10% of current users of genetic engineering plan to decrease investment in this technology, suggesting that public opposition to genetically engineered crops has not led these firms to move towards alternatives, although it could have slowed the advance of genetic engineering. Another explanation of these results is linked to the long time-line for the development of new seed varieties, which can take between eight and twelve years. It could be difficult for firms to alter their technological choices part way into a project.

Both current users of assisted conventional breeding and of conventional breeding alone are shifting investment from conventional breeding to assisted conventional breeding, and secondarily to genetic engineering. However, the shift out of conventional technology is highest for current users of assisted conventional methods. Again, this probably reflects the benefits of existing familiarity with more advanced technology.

4.2.2 Employment

The questionnaire obtains information on each firm's total employment, the number of employees involved in developing or field testing new varieties[46], and an estimate of the number of new developmental employees by 2002. Table 4.7 provides employment results by technology class. It is important not to interpret the expected increase in the number of developmental employees as reliable point estimates. Survey respondents tend to give optimistic answers to questions on growth and employment, which could be particularly questionable in this sector, due to the recent number of mergers among agro-seed firms. Of greater interest and reliability is the *relative* difference in expected employment by the most advanced technology in use.

[46] Developmental employees include staff active in research, field testing, regulatory compliance, and relevant management tasks.

Table 4.7 Employment by most advanced type of technology currently in use

Most advanced technology in use	1999 total employees	1999 total development employees[1]	Estimated extra development employees[2] in 2002	% increase in development employees
Genetic engineering	9,405	2,308	174	7.5%
Assisted Conventional	2,488	961	54	5.6%
Unassisted conventional	1,853	404	43	10.6%
Survey total	*13,746*	*3,673*	*271*	*7.4%*
Entire population Est.[3]	*19,161*	*5,120*	*378*	

1: Development or field testing of agricultural seed or plant varieties, including relevant employment in research, field testing, regulatory compliance, and management.

2: Two firms using genetic engineering and two firms that only use unassisted conventional plant breeding did not provide an estimate of the expected change in employees. For these four firms, extra employment is estimated from the average rate of change for other firms in their technology use class.

3: Crude extrapolation to the entire population of seed firms, based on the assumption that the distribution of employees is identical among an estimated 39 eligible firms that did not respond to the survey.

The total number of development employees is expected to increase by 7.4%. The highest rate of increase is among firms that currently do not use advanced technologies, although the difference from the average is not statistically significant. In addition, there are no statistically significant differences in the mean change in development employees by size class. By country, the largest expected growth in development employees is in the UK (13%), followed by the Netherlands (10%) and Spain (10%). Expected growth rates in Denmark, Germany and France vary between 2% and 5%.

4.2.3 Employment growth and future technology use

The results given in Table 4.7 suggest that there is no significant difference in the growth rate for developmental employees by the most advanced technology in use by a firm. However, as shown in Table 4.5, 73.4% of the employment-weighted development budget in 1999 used conventional plant breeding technology. We still need to answer the question: Is there a difference between the expected change in employment of development staff and the expected change over three years in the distribution of investment by technology class? One possibility is that a planned shift in investment towards advanced technology such as genetic engineering or assisted conventional breeding could increase employment among development staff, either to acquire further expertise in these technologies or to exploit opportunities to develop new plant varieties.

Analyses of planned technology use among the 43 firms that only used conventional plant breeding in 1999 found no statistically significant differences in the average expected increase in employment by their plans to use advanced technology. The employment weighted average increase in the expected number of development employees is 12.3% for 20 firms that do not plan to adopt any of the two more advanced technologies, 8.2% among 14 firms that plan to adopt assisted conventional technology, and 11% among nine firms that plan to adopt genetic engineering.

The relationship between the rate of increase in development employees and the percentage change in the current and expected investment were explored in a series of correlation analyses limited to users and non-users of each of the three development technologies.

None of the six correlations are statistically significant, although the small sample size reduces the probability of finding a significant difference (see Table 4 in Appendix III). These results suggest that employment growth is not linked to either an increase in the use of genetic engineering or assisted conventional technology nor to the widespread decrease in the use of conventional plant breeding technology. Instead, there are no differences in the expected change in development employees that can be attributed to the type of developmental technology in use.

4.2.4 Employment, sales and exports

An important factor influencing employment is the export rate, or the percentage of total sales outside of the EU. The export rates provides a measure of the fraction of employment that is unaffected by policies that influence domestic consumption. Export rates also suggest where employment could increase in the near future, due to rising demand in other countries.

Table 4.8 gives sales-weighted results for the export rate by the most advanced technology in use and by the planned technology in use for 2002[47]. By 1999 technology use, the highest export rate of 37.1% is among firms that use assisted conventional breeding methods.

Table 4.8 Sales-weighted export rates by technology type: limited to firms with current sales and which reported export rates[1]

	Current use in 1999		Planned use for 2002	
Most advanced technology in use	N	% Sales from exports	N	% Sales from exports
Genetic engineering	21	20.2	34	18.2
Assisted conventional	18	37.1	22	46.6
Unassisted conventional	31	11.3	14	14.1
Total firms	*70*	*24.6*	*70*	*24.6*
P value for difference by most advanced technology in use		.001		.000

1: 13 firms did not answer the question on the percentage of sales due to non-EU exports, while sixteen firms had zero sales. Results are almost identical when three firms with imputed sales above zero are excluded.

The results for planned use provide some clues on the relationship between current export rates and future strategies. The fact that the 1999 export rate for firms that plan to use assisted conventional technology in 2002 increases from 37.1% to 46.6% indicates that firms that currently use unassisted conventional technology and which plan to adopt this technology have higher export performances, on average, than firms that do not plan to adopt this technology. Interestingly, the export performance of firms that plan to adopt genetic engineering is lower than average, as shown by the slight fall in export sales from 20.2% to 18.2% once potential adopters in 2002 are added to the genetic engineering group. Apparently, the adoption of genetic engineering is unlikely to lead to higher exports for Europe, since firms that use or plan to use this technology are less export intensive than firms using assisted conventional technology. One explanation is that many of these firms are multinationals that serve their export markets from their foreign subsidiaries.

Another possible outcome is that the average sales per development employee could vary by the most advanced technology in use. For example, firms that use genetic engineering could have lower sales per development employee because of high initial research costs, or alternatively sales among conventional plant breeders could be falling per research worker because they are less capable of developing competitive new varieties. However, as shown in Table 4.9, there are only minor differences in the average sales per development worker.

[47] Sixteen of the 99 respondent firms had no sales in 1998 and are therefore excluded from the analyses of export rates. All sales data was first converted into Euros.

None of the means differ significantly from the average, although there is an apparent decline in the sales per development worker as the technology becomes more advanced. The results are given for both firms with positive sales only and for all firms combined. The latter group provides a measure of total sales across the total number of development employees. In addition, there are no significant correlations between the percentage of the development budget spent on each technology and the amount of sales per development employee.

Table 4.9 Mean sales (in '000 Euros) per development employee by the most advanced technology in use

Most advanced technology in use	N	Firms with positive sales only	N	All firms[1]
Genetic engineering	26	761	33	682
Assisted conventional	20	900	23	782
Unassisted conventional	37	937	43	795
Total firms	*83*	*815*	*99*	*721*
P value for difference by technology in use		ns		Ns

1: 16 firms report zero sales. The average sales per development worker is determined from the sum of all sales and all development employees in each technology use category. The results are similar when 16 firms with imputed sales (including two with imputed zero sales) are excluded from the analyses.

4.3 Results of the Survey of PPP Firms

Table 4.10 provides the number of respondent firms by country that actively develop new pesticides and the number of employees within these firms. Over half of the total employment among firms that develop pesticides is in Germany.

Table 4.10 Number of responses by country for firms that develop new pesticide varieties

Country	Number of firms	Percent of total firms	Number of employees[1]	Percent total employees
UK	13	23.2	1,229	8.9
France	14	25.0	2,556	18.4
Germany	6	10.7	7,896	56.9
Netherlands	8	14.3	352	2.5
Denmark	5	8.9	933	6.7
Spain	10	17.9	903	6.5
Total	56	100%	13,869	100%

1: Employee counts imputed for eight firms.

4.3.1 Development of new PPPs

Respondents were asked if their firm developed chemical pesticides, bio-pesticides, and chemical/crop combinations. The latter includes herbicide tolerant crop varieties plus several developing technologies, such as fungicides plus fungus resistance or genes that can be turned on or off with chemical exposure. An example is a gene that stops stored potatoes from sprouting until exposed to a chemical that activates the sprouting process.

Table 4.11 gives the distribution of respondent firms and employees by the type of pesticides that the firm develops. Almost half (47.3%) of employment is in firms that only develop chemical pesticides, while another 36.8% of employment is among firms that develop chemical/crop combinations in addition to chemical pesticides. Firms that develop all of the three types of pesticides are kept in a separate category.

Table 4.11 Distribution of respondent firms by type of pesticides that are developed

Pesticide type	Firms	Percent	Employees	Percent
Only chemical pesticides	22	39.3	6,566	47.3
Bio-pesticides[1]	17	30.4	1,299	9.4
Chemical plus chemical/crop combinations	11	19.6	5,108	36.8
All three types	6	10.7	896	6.5
Total	*56*	*100.0*	*13,869*	*100.0*

1: The firm can also develop either chemical pesticides or chemical/crop combinations.

Firms that develop bio-pesticides are smaller than average, accounting for 30.4% of the firms but only 9.4% of total employment. Firms that only develop chemical pesticides or chemicals plus chemical/crop combinations are larger than average.

Table 4.12 gives the employment-weighted share of the development budgets that are allotted to each of the three types of pesticides. Chemical pesticides dominate both current budgets and the expected budgets for 2002, although the share of the development budget for chemicals is expected to decline from 87% in 1999 to 81.7% in 2002.

Table 4.12 Distribution of current and expected pesticide development budgets by type of pesticide (Employment weighted)

Development technology	1999	2002	% Change
Chemical pesticides	87.0	81.7	- 6.1%
Bio-pesticides	6.0	6.4	+ 6.7%
Chemical/crop combinations	7.0	11.9	+ 70.0%
	100%	*100%*	

Most of this decline will be replaced by an increase in the development budget for chemical/crop combinations. Only 6% of current development budgets are allotted to the development of bio-pesticides, although this is expected to increase slightly to 6.4% in 2002. These results indicate that investment is primarily shifting, albeit slowly, from chemical pesticides to chemical/crop combinations, with only a small sift in favour of bio-pesticides.

Table 4.13 gives the employee-weighted percentage of firms that report a planned increase, no change, or a decrease in the share of their pesticide development budget that is allotted to each technology. None of the firms plan to increase their budget share for chemical pesticides, while 41.8% plan to decrease this percentage. The largest percentage increase is for chemical/crop combinations, where 32.7% of firms plan to increase the fraction of their investment allotted to this technology. Very few firms plan to decrease the share of their investment in chemical/crop combinations. Most of the planned increase in the development budget for bio-pesticides is among firms with less than 100 employees.

Table 4.13 Percent of firms that plan to increase, leave unchanged, or decrease the share of their development budget for specific pesticides

	Chemicals		Bio-pesticides		Chemical/crop combinations	
	Firms	Employees	Firms	Employees	Firms	Employees
Increase	0.0	0.0	18.2	5.9	32.7	41.8
No change	58.2	56.8	74.5	86.9	65.5	57.9
Decrease	41.8	43.2	7.3	7.2	1.8	0.3
	100%	*100%*	*100%*	*100%*	*100%*	*100%*

The high percentage of firms in the ‘no change’ category for bio-pesticides and chemical/crop combinations is due to firms that do not currently use each technology and which also have no plans to adopt it. The percentage of firms that neither develop nor plan to develop each type of pesticide is as follows: 12.7% for chemicals, 51% for bio-pesticides, and 63.6% for chemical/crop combinations. The employee-weighted percentages are 4.9% for chemicals, 78% for bio-pesticides, and 55.9% for chemical/crop combinations.

4.3.2 Employment

Table 4.14 provides the total number of employees among firms that develop new types of pesticides, the number of employees that are involved in development tasks, an estimate of the number of new development employees by 2002, and the percentage increase in development employees.

The total number of development employees is expected to increase by 3.3%, which is less than half of the expected increase of 7.4% for seeds firms. Furthermore, the average increase varies considerably by the type of pesticide that the firm develops[48]. The number of developmental employees among firms that only develop chemical pesticides is expected to increase by 0.7%, followed by an increase of 5.2% among firms that develop chemical/crop combinations. In contrast, the number of development employees is expected to increase by 26.6% among firms that develop bio-pesticides, although from a very small base. These firms only account for 5.8% of current development employees.

[48] The difference is statistically significant, with $p < 0.01$.

Table 4.14 Employment by the types of pesticides developed by the firm

Pesticide	1999 total employees	1999 total development employees[1]	Estimated extra development employees[2] in 2002	% increase in development employees
Only chemicals	6,566	1,699	12	0.7%
Bio-pesticides	1,299	184	49	26.6%
Chemical + chem/crop combinations	5,108	1,004	52	5.2%
All three types	896	288	-8	-2.7%
Survey total	*13,869*	*3,175*	*105*	*3.3%*
Entire population Est.[3]	*19,318*	*4,442*	*146*	

1: Includes employees in research, trials, and related management.

2: One firm that only develops chemical pesticides, one firm that develops bio-pesticides, and one firm that develops chemical/crop combinations did not provide complete data on current development employees and/or the expected change in employment. Missing values for these firms are estimated from the average for other firms that develop the same class of pesticides.

3: Crude extrapolation to the entire population of firms that develop pesticides, based on the assumption that the distribution of employees is identical among an estimated 22 eligible firms that did not respond to the survey.

The relationship, at the firm level, between the expected change in the number of development employees and the type of pesticides developed by the firm were explored using correlation and regression analyses. None of the results were significant. The best predictor is a categorical variable in which the change in investment can either increase, decrease, or remain unchanged. Using this variable, the average expected increase in development employment is higher among firms that plan to increase investment in bio-pesticides, although the difference is only significant at the 10% level.

4.3.3 Employment, sales and exports

Only 40 of the 56 pesticide firms have positive sales, and of these only 31 provide the percentage of their production that is exported outside of the EU. Table 4.15 gives sales-weighted results for these 31 firms for the percentage of exports by pesticide class. The differences in export rates by class are not statistically significant.

Table 4.15 Sales-weighted export rates (to non-EU countries)

Pesticide class	N	% sales from exports
Only chemicals	13	52.8
Bio-pesticides	10	52.3
Chemical + chem/crop combinations	7	59.0
All three types	1	40.0
Total	*31*	*55.3*

There is also no significant difference by pesticide class in the average sales per development employee. These results are given in Table 4.16. Nor are there any significant correlations between the percentage of the current development budget spent on each type of pesticide and the amount of sales per development employee.

Table 4.16 Average sales (in '000 Euros) per development worker by pesticide type: limited to firms with positive sales or positive plus zero sales

Pesticide class	N	Firms with positive sales only	N	Firms with positive or zero sales[1]
Only chemicals	16	2,200.9	22	2,089.5
Bio-pesticides	13	2,369.5	17	1,751.4
Chemical + chem/crop combinations	9	4,133.7	11	4,080,1
All three types	2	2,453	6	1,916.5
P value for difference	*40*	*ns*	*56*	*ns*

1: 16 firms report zero sales. The average sales per development worker is determined from the sum of all sales and all development employees in each pesticide class.

4.4 Conclusions

The conclusions cover both seeds and PPP firms.

4.4.1 Seeds Firms

Three plant breeding technologies are available for seed firms: genetic engineering, assisted conventional breeding that uses advanced techniques such as marker genes and gene sequencing, and conventional or classical plant breeding. Genetic engineering, based on advanced biotechnology, has attracted considerable attention by policy makers, partly because this technology is thought to have major potential benefits, both commercially and environmentally.

The survey results show that genetic engineering accounted for an estimated 10.2% of the total budget, compared to 16.5% for assisted conventional breeding and 73.4% for conventional technology. A maximum estimate of the share of genetic engineering to develop new seeds is 38%, based on the assumption that conventional breeding is only used to test varieties that are developed via genetic engineering or assisted conventional techniques.

Between 1999 and 2002 the number of firms with genetic engineering capabilities is expected to increase from 33% to 49% of respondent firms, while the percentage using assisted conventional technology will increase from 23% to 31%. However, the share of the total development budget allotted to genetic engineering is only estimated to reach 14.7% in 2002, with a maximum estimate of 36%. Seed development will still be dominated by methods that do not use genetic engineering.

The survey results, once extrapolated to non-respondent firms, estimate that there are approximately 5,000 employees active in the development of new seed varieties in the six EU countries covered by this survey. The number of development employees is expected to grow by an average of 7.4%. It is important to note that this estimate is probably unreliable, due to the number of mergers in this industry.

In comparison with other countries such as Canada and the United States, Europe has a less favourable regulatory and market environment for genetically-engineered seeds. One possibility is that these unfavourable conditions could act to reduce direct employment by European seed firms by discouraging European firms from investing in genetic engineering. However, the survey results suggest that existing conditions in Europe are unlikely to lead to employment reductions in the short term.

First, only a third of European firms have the ability to develop genetically engineered seeds and only 10% of total investment is in this technology. This reduces their exposure to the effects of unfavourable markets for genetically-engineered crops. At the same time, European seed firms are rapidly developing capabilities in genetic engineering and the application of advanced biotechnology techniques such as marker technology and gene sequencing to conventional breeding methods. By 2002, almost half of seed firms will have some capability in genetic engineering while another 30% will be able to use assisted conventional techniques. This suggests that European seed firms will be able to succeed in either a favourable or hostile environment towards genetically-modified crop varieties.

Second, expected changes over the next three years in the number of developmental employees does not differ by the most advanced type of technology in current use. Firms that currently use genetic engineering do not expect the number of their development employees to grow more quickly or more slowly than other firms. It is important to emphasize that this result applies to *all* seed firms. The expected growth in development employees among dedicated agro-biotechnology firms that focus on genetic engineering is faster than the average (as discussed below), although based on small initial employment levels.

Third, there are no statistically significant differences in the average sales per development worker by the most advanced type of technology in use. This is one measure of the efficiency with which firms can translate development costs into sales. However, there is one drawback to this measure, which is that current sales levels reflect investment before the survey, while current investment levels in different technologies will determine future sales. Therefore, these results are only valid if the distribution of investment across the three development technologies has only been changing slowly in the past.

Although the results do not support a reduction in employment in European seed firms, the number of developmental employees could be growing more slowly than it would under a more favourable environment for genetically-engineered seeds. One possibility is that an unfavourable environment for genetic engineering in Europe, while having no effect on domestic sales, could negatively influence employment by reducing exports. On first sight, this does not appear to be a valid concern because export rates to countries outside of the EU are almost twice as high among users of assisted conventional technology than among users of genetic engineering. This suggests that the use of genetic engineering *reduces* rather than increases the ability to export, which is unlikely.

An more convincing explanation for lower export rates among firms that use genetic engineering is linked to the ownership structure of seed firms. The 33 firms with genetic engineering capabilities include small firms with a focus on genetic engineering and low or zero sales, mid-sized independent firms, and large multinational firms. The majority of the small firms have no sales and hence no exports, while the large multinational firms can serve export markets from their foreign subsidiaries. This will apply to seed varieties developed either by genetic engineering or conventional breeding. Regardless of the environment for genetic engineering in Europe, multinational seed firms can serve export markets from their foreign subsidiaries, in the same way that several non-European seed firms, such as Monsanto, DuPont, Seminis, and Pioneer Hibred, partly serve the European market from their European subsidiaries.

One group of European seed firms could be experiencing lower than expected employment growth due to the unfavourable environment in Europe for genetically-modified seeds: firms that allot a high percentage of their seed development budget to genetic engineering. Eleven of the respondent firms allot more than 20% of their budget to genetic engineering, while seven of these firms allot more than 80% of their budget to this technology. The expected growth in development employees among these firms is 14% and 26% respectively, which is faster than the average for all seeds firms of 7.4%.

How does this growth rate compare to that of comparable firms in countries with a more favourable environment for genetically engineered seeds? Some data that is relevant to this question is available from a 1998 Canadian survey of biotechnology firms, conducted by Statistics Canada. This survey obtained results on the expected growth in R&D employees over a three-year period between 1998 and 2001. The average expected increase for 14 Canadian firms that use genetic engineering for plant biotechnology is 63%, which is over double the rate of 26% for the seven European biotechnology firms[49]. Of course, this comparison is only suggestive, since it is based on a small number of firms and there are differences in the eligibility criteria for each survey.

4.4.2 PPP firms

The results for firms active in pesticides paint a picture of a more stable sector than the seeds sector. The majority of the investment budget is spent on chemical pesticides, with only a small shift towards chemical/crop combinations expected in three years. Bio-pesticides only attract 6% of the estimated 1999 development budget. This contrasts with much more rapid changes in investment budgets in the seeds sector.

The number of development employees in pesticide firms is expected to grow at less than half the rate for the seeds sector. Unlike the seeds sector, however, there is a difference by the type of technology under development. Firms active in bio-pesticides have an expected growth rate in development employees of 26.6%, which is much faster than the average for all other firms of 3.3%.

With this exception, the low expected growth rates for development employees in the pesticides sector needs to viewed in terms of the long-term decline in total employment in industrial chemicals in Europe, which includes pesticide firms. Slightly positive growth rates for development employees, against a decline in overall employment, suggests a gradual shift in this sector towards research positions.

One possibility is that total employment in pesticide firms will continue to decline, or decline more steeply, because of a loss of markets, with farmers replacing pesticides with pesticide-resistant crops developed by seed firms. Pesticide firms have several strategic options in the face of this challenge. They can develop less toxic chemical or bio-pesticides that are cost-effective alternatives to pest resistant seeds, which command premium seed prices. Alternatively, they can shift from pesticides towards chemical/crop combinations. This requires developing expertise in plant breeding. It is also the strategy pursued by AgrEvo. The survey results indicate that the option of developing bio-pesticides is mostly limited to smaller firms. The large firms are shifting some of their investment budget towards chemical/crop combinations, albeit at a very slow rate.

5. CONCLUSIONS

Advanced biotechnology provides new technical opportunities for developing improved crop seed varieties and new types of plant protection products (PPPs). This report qualitatively assesses the potential effects of new technical opportunities on 1) employment in the European agro-food chain and 2) the competitiveness of European seed and PPP firms. The evaluation is based on both a review of the literature and on new research. The latter includes analyses of relevant surveys in Europe and Canada, a series of interviews with Europe’s largest seed and PPP firms, a new survey on the use of different technologies by these firms, and an analysis of the European database on field releases of GMOs.

Employment in the agro-food chain occurs in five main levels: manufacturers of agricultural inputs (which includes seeds and PPPs), on the farm, transportation and distribution, food and industrial processing, and the retailers of food products. The innovative activities of firms in the seed and PPP sectors can influence employment patterns through the first four levels.

[49] Results for Canada are presented here by permission of the SIEID division of Statistics Canada. The analysis of the Canadian *Biotechnology Firm Survey–1997* is by the author.

5.1 Major factors reducing employment in the agro-food chain

The innovation strategies of seed and PPP firms is only one of several influences on employment in the agro-food chain. Four other factors are reducing jobs in the agro-food chain:

- A long-term decline in employment among input suppliers, farmers, and food processors due to productivity increases from labour-saving innovation. Innovation surveys show that downstream food processors attach a high importance to reducing direct labour costs and the cost of material and energy inputs as a goal of innovation. The latter will reduce employment among upstream suppliers such as seed and PPP firms.
- Agricultural subsidies have kept farm employment in Europe above its market level, as shown by a drop in the gross value added of European agriculture in the 1990s. This decline has been met by an increase in subsidies. A decline in the gross level of agricultural subsidies in Europe, due to CAP reform or world trade agreements, should decrease agricultural production in Europe. This would result in reduced employment not only on the farm, but also in transport and distribution and among agricultural input suppliers such as seed and PPP firms.
- Slow population growth in the EU, plus an inelastic demand for commodity crops, constrains growth in the European agricultural market and consequently among input suppliers.
- Mergers within the seed and PPP sectors over the last five years have reduced employment. The mergers are partly driven by the cost of advanced biotechnology and the need to access patent rights.

5.2 Innovation options and employment

The effect of innovation in the seed and PPP sectors on employment depends on the type of innovation. There are five main options for innovation in plant breeding. These are 1) an increase in yields per hectare, 2) an increase in yields per unit of inputs, 3) reduction in risks to the farmer, 4) input switching with no change in yield, and 5) improved quality characteristics for feed, food, and industrial uses. Each has a different impact on both the location of employment effects within the agro-food chain and whether or not employment is likely to increase, decrease, or remain unchanged. The discussion of these effects assumes no increase in exports, no change in current agricultural subsidy levels, and inelastic demand for commodity agricultural products.

An increase in per hectare yields is likely to decrease farm level employment, while an increase in yields per unit of input is likely to decrease employment among input suppliers such as seed and PPP firms. A reduction in risk to the farmer could increase employment among input suppliers but result in a loss of jobs on the farm. Input switching, such as when farmers use a GM crop that is resistant to a proprietary herbicide rather than an alternative variety of the same crop plus herbicides, could have no effect on total employment, but shift employment from one input supplier to another.

5.2.1 Quality traits

Only quality characteristics, by increasing the value-added of agricultural products and therefore the price that can be charged for them, are likely to lead to aggregate employment growth in the agro-food chain. Such growth will most likely occur among seed firms, on the farm, and in transport and distribution, as a result of the additional costs of identity preservation. Quality characteristics could result in a decline in employment among food and industrial processors due to greater processing efficiencies. In addition, quality improvements that permit agricultural inputs to replace mineral resources or industrial inputs could result in employment losses outside of the agro-food chain.

The interviews with the seed firms show that many of them plan to apply genetic engineering to develop quality traits. However, the field trial data for GMOs in Europe show that 70% of all trials so far are for herbicide tolerance and pesticide resistance. The share of quality traits increased between 1991 and 1997, but has remained relatively stable since then, at about 20% of all trials. These results show that there has only been a small shift to quality traits. It is also possible that research on quality traits has not yet reached the field test stage. If true, it will be at least five to seven years before most GM quality traits begin to reach European markets and thereby influence employment.

5.2.2 Quality traits and the pharmaceutical business model

Several of the largest seed firms, possibly because of a goal (since mostly abandoned) to develop synergies with their pharmaceutical divisions (i.e. Novartis and Monsanto), appear to be moving towards a pharmaceutical business model for developing new seed varieties. This model is based on two main business strategies: First, to develop products that appeal to wealthy consumers who are willing to pay high prices for marginal product improvements and second, to vigorously use patents and other intellectual property rights (IPRs) to ward off competitors and maintain profit margins.

The closest that seed firms can get to a pharmaceutical product line is to develop high value-added quality traits. They offer the best option for increasing profits and growth, as long as the additional value of the product (and the price that can be charged for it) exceeds the development costs plus the identity preservation costs. The enthusiasm for functional foods and “neutraceuticals” by some seed firms is explained by the lure of even higher prices and profit margins, because of the potential appeal of these products to wealthy consumers.

The response of policy makers to the adoption of a pharmaceutical business strategy by seed firms is generally positive. One reason for this positive attitude is the observation of a 20% increase in employment in the pharmaceutical sector between 1978 and 1992, compared to declines in most other manufacturing sectors. Employment increases have also been observed in other high technology sectors within some OECD countries and within the telecom equipment sector in Europe (Pianta et al, 1996; OECD, 1996). These two trends have encouraged policy makers to link high-technology sectors such as pharmaceuticals and advanced biotechnology with increasing employment and competitiveness.

Yet, there could be several problems with the adoption of the pharmaceutical model by seed firms. The business strategy of pharmaceutical firms depends on a market that is not price sensitive, which permits pharmaceutical firms to recoup high investments in R&D and even higher investments in marketing. In contrast to pharmaceuticals, the market for agricultural products, including seeds, is both price sensitive, competitive (Bijman, 1999), and characterised by low switching costs. Public resistance could further reduce the market price for GM crops. GM functional foods could also face the same problems as other agricultural products, such as competitive alternatives.

The pharmaceutical model also depends on IPRs such as patents and trademarks to maintain high prices. However, there is a limit to the ability of seed firms to use IPRs in this manner, due to the ease with which farmers, food processors, and industrial processors can substitute one input or production method for another. Low input switching costs for farmers and processors will limit the prices that seed and PPP firms can charge for their products, including new seed varieties based on quality traits. Seed firms could also face difficulties in protecting patent or trademark rights over specific food characteristics. For these reasons, it remains to be seen if the pharmaceutical model can be successfully applied to the seed sector on a long-term basis.

5.2 Innovation by PPP firms and employment

Two of the innovation strategies available to PPP firms, the development of new chemical and bio-pesticides, are most likely to decrease or have no effect on employment, although there could be strong product substitution effects and consequent job losses or gains among competing firms.

One possibility is that total employment in pesticide firms will continue to decline, or decline more steeply, because of a loss of markets, with farmers replacing pesticides with pesticide-resistant crops developed by seed firms. Pesticide firms have several strategic options in the face of this challenge. They can develop less toxic chemical or bio-pesticides that are cost-effective alternatives to pest resistant seeds. Alternatively, they can shift from pesticides towards chemical/crop combinations, such as seeds that respond to chemical switches that turn on or off desirable traits. This requires developing expertise in plant breeding. It is also the only innovation option open to PPP firms that is likely to increase employment (in a stagnant European market) through an increase in value-added. The survey results show that the percentage of the total PPP development budget that is allotted to chemical-seed combinations is expected to increase from 7% of the total in 1999 to 12% of the total in 2002. Employment among PPP firms could also increase as a result of the adoption of quality-enhanced seeds, which could encourage farmers to purchase more PPPs in order to protect their investments in higher value crops.

The survey obtained estimates of the growth in developmental employees (including R&D staff) in the seed and PPP sectors. The total number of development employees between 1999 and 2002 is expected to increase at about half the rate among PPP firms as among seed firms–3.3% versus 7.4%. Unlike the seeds sector, however, there is a difference by the type of technology under development. Firms active in bio-pesticides have an expected growth rate in development employees of 26.6%, albeit from very low initial levels, but an increase in bio-pesticide use will likely result in job losses in the production of chemical pesticides.

With the exception of bio-pesticides, the low expected growth rates for development employees in the PPP sector needs to viewed in terms of the long-term decline in total employment in industrial chemicals in Europe, which includes PPP firms. Slightly positive growth rates for development employees, against a decline in overall employment, suggests a gradual shift in this sector towards higher skilled research positions.

5.3 Exports and import substitution

The high cost of developing new PPPs that meet strict environmental regulation and the cost of using genetic engineering to develop new seed varieties are encouraging seed and PPP firms to seek large product markets to cover development costs. This is leading firms to concentrate their efforts on a limited number of products and to seek global markets for them.

Success in global markets could result in net increases in European employment through an increase in exports. However, there are technical limits on the ability of European seed firms to serve export markets with European grown seed, since seed varieties need to be adapted to local market conditions. This means that many seed varieties are both tested and grown locally. The result is that the employment effects in Europe from expansion into Asian, North American or Latin American seed markets is likely to be limited to upstream R&D and management. The same shift towards higher skilled jobs in Europe could also occur in the PPP sector, although many export markets are likely to be served by a combination of European and foreign production. These differences show up in the survey results. The export rate to non-EU countries of 55% for PPP firms is over twice as high as the 25% rate for seed firms.

Import substitution, in which European production replaces imports, could also increase net European employment. An example is high lauric acid rapeseed to replace imports of coconut and palm oil.

5.4 Innovation and competitiveness

Unfavourable market and regulatory conditions for GM crops in Europe could reduce the competitiveness of European seed firms if GM crops were positively linked to higher sales and profits and if European seed firms were discouraged from developing expertise in genetic engineering. The results of the survey of European seed firms, plus other data, show that fears about the competitiveness of European seed firms are unfounded, at least over the short term of the next two to five years. There are three reasons for this conclusion.

First, only a third of European firms have the ability to develop genetically-engineered seeds and only 10% of total investment in developing seeds is in this technology. This reduces their exposure to the effects of poor markets for GM crops. At the same time, European seed firms are rapidly developing capabilities in genetic engineering and the application of advanced biotechnology techniques such as marker technology and gene sequencing to conventional breeding methods (Arundel *et al*, 2000). By 2002, almost half of seed firms will have some capability in genetic engineering while another 30% will be able to use assisted conventional techniques.

One reason for these comparatively low investments in genetic engineering is the small market share of the main potential GM crops in Europe, which are oilseeds, maize, sugar beets and potatoes. These four crops account for only 16.3% of the total 1997 value of European crops. In contrast, “small market” crops such as vegetables, fruits, and vine crops account for 52.5% of crop values while other cereals (mostly wheat) account for another 17%. The application of advanced biotechnology to these crops could require several technical advances, particularly for wheat, plus a significant fall in the cost of genetic engineering.

Second, expected changes over the next three years in the number of development employees (including R&D employees) does not differ by the most advanced type of technology in current use. Firms that currently use genetic engineering do not expect the number of their development employees to grow more quickly or more slowly than other firms.

Third, there are no statistically significant differences in the average sales per development worker by the most advanced type of technology in use. This is one measure of the efficiency with which firms can translate development costs into sales. Nor are export rates to countries outside of the EU higher among firms that use genetic engineering compared to firms that only use assisted conventional or classical breeding methods.

These results show that European seed firms are rapidly building competences in genetic engineering, while hedging their bets. Therefore, European seed firms should be able to remain competitive in either a favourable or hostile environment towards GM crops.

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APPENDIX I : Methodology of the Statistics Canada, CIS and PACE Surveys

Canadian Survey Of Biotechnology Use–1996

The results given above from the 1996 *Survey of Biotechnology Use in Canadian Industries* are drawn from four publications (Rose, 1998; Arundel and Rose, 1998; Arundel, 1998; Arundel and Rose, forthcoming).The Survey of Biotechnology Use surveyed all firms in Canada that met two criteria:

- Annual sales in 1995 exceeded 5 million Canadian dollars (approximately 3.6 m US).
- The firm's main sector of activity was within one of 17 industrial sectors (defined at the two-digit level) where biotechnology was thought to have possible applications.

The survey was sent to 2,298 firms that met the two selection criteria. Responses are available for 2,010 firms, or 87.5% of the original sample. It is important to note that the selection criteria excluded several types of firms of interest to agro-biotechnology: small research intensive biotechnology firms, firms that have yet to market a product, and agricultural firms such as seed firms or firms involved directly in agricultural production. The main value of the results concern the use of biotechnologies by food processing and agrochemical firms.

The survey questionnaire avoids widespread confusion over the meaning of "biotechnology" by asking about the use of 22 carefully-defined biotechnolog*ies*. These are grouped into three main classes. The first class consists of eight biotechnologies used in the modification of cells and genetic material, including two core technologies for genetic engineering that are relevant to agro-biotechnology. The second class includes five environmental technologies that use micro-organisms or plants to break-down or remove hazardous substances. The third class consists of nine biotechnologies with applications in food production and industrial processes, ranging from tissue culture to fermentation technology.

Separate questions for each of the 22 biotechnologies ask which of four stages best reflects the function of biotechnology "within your business activities". The four stages consist of "research" plus three applications: "part of the production process", "part of the product sold", or "part of a pollution control system". Non-users of each biotechnology are asked if they plan to adopt the technology within the next two years. The questionnaire also contains question groups on the benefits from the use of each class of biotechnology.

Results are available both for the firm and after weighting by the number of employees[50]. The use of employee-weighting assumes that there is a direct correlation between the size of a firm, as measured by the number of employees, and the use of a specific biotechnology. This assumption is not always reliable because a firm with many different establishments might only use biotechnology in one of them–which could even be the smallest establishment. In general, the employee-weighted results will tend to bias upwards the true use of a biotechnology. In order to limit the extent of this bias, firms with ten or more establishments were excluded from the employee-weighted results. These firms are, however, included in the firm-level results.

Some of the published results are for an group of sectors that are potential users of agricultural biotechnology. These sectors include:

- Fishing
- Food products, including poultry, canning, dairy, feed industry, oils, bakery products, etc
- Beverages, including distillery products, breweries and the wine industry

[50] The employee-weighted results are equal to the percent of all employees in firms that use a specific biotechnology out of the total number of employees among all relevant firms that responded to the survey.

- Tobacco products
- Chemical sub-sectors of possible interest, including industrial organic chemicals (n.e.c), fertilisers, and other agricultural chemicals[51].

For simplicity, these sectors are referred to as the agro-food sector. In total, responses were received from 797 firms active in this sector. Nine of the 22 biotechnologies involve agricultural, food processing applications, or genetic engineering: recombinant DNA, DNA amplification, tissue culture, somatic embryo-genesis, bio-pesticides, classical/traditional breeding, bio-processing, bio-sensing, and microbio-inoculations. These nine biotechnologies are termed agro-food biotechnologies in Arundel and Rose (forthcoming).

Canadian Biotechnology Firm Survey–1997

The *Biotechnology Firm Survey – 1997* was sent to firms in Canada that were thought to perform biotechnology R&D. Contact was made with 330 firms and responses were received from 210, for a response rate of 63%[52]. Of these, 199 firms performed biotechnology R&D. An expert evaluation of the respondent and non-respondent firms indicates that replies were obtained from almost all major players in biotechnology R&D in Canada.

A key question in the 1997 survey asked for the number of current biotechnology employees for seven different activities: R&D, clinical affairs/quality assurance, regulatory/legal/government affairs, manufacturing, marketing and sales, business development/finance, and administration/human resources. Firms are classified into four main bio-industry sectors, based on their responses to their involvement in 17 main biotechnology activities. The survey also asks about the use of 17 biotechnologies: five based on DNA, seven based on biochemistry, and five used for bioprocessing.

The Community Innovation Survey (CIS)

The 1993 European Community Innovation Survey (CIS) is the largest innovation survey to date[53]. Responses are available from approximately 35,000 manufacturing firms in the 12 member states of the EU in 1993 plus Norway. However, the results for four countries are excluded because of problems with the data; the UK, Greece, Portugal and Spain, while the food sector, which is of great interest to PITA, was not included in the French survey. The analyses given below are therefore limited to responses from eight European countries[54]. They are also limited to manufacturing firms with more than 20 employees that introduced one or more product or process innovations during the three year period before the survey. All of the analyses are based on questions that ask the respondent to estimate the 'importance' of an outcome, using a subjective scale with five options: not important, slightly important, moderately important, very important, and crucial.

One major drawback to the use of the CIS to investigate issues of importance to PITA is that it does not include agricultural firms and it is not possible to identify firms that are active in biotechnology. We do not know if the innovative activities of these firms concern biotechnology or not.

Two sectors of relevance to PITA can be identified using the CIS: food and beverages and agro-chemicals. Responses are available for up to 901 innovative firms in the food and

[51] This list excludes the pharmaceutical sector, which develops veterinary products.

[52] Eleven percent of firms that replied to the 1997 survey also responded to the 1998 survey.

[53] The second CIS, implemented in 1997 and possibly available in early 1999, will probably be larger.

[54] Norway, Luxembourg, Denmark, Ireland, the Netherlands, Belgium, Italy, and Germany.

beverages sector. Unfortunately, there are only x respondents from the agro-chemical sector[55].

The CIS results are corrected using weights provided by Eurostat to adjust for the response rate in strata that are defined by country, industry, and firm size. The results are also employee-weighted. Three technology-based comparison groups are provided for the food sector: low, medium and high technology. The food sector itself is considered to be a low technology sector, based on its own expenditures on innovation[56].

The PACE Survey

The PACE survey was sent to selected R&D managers from Europe’s 500 largest industrial firms in the Spring of 1993. Although the survey is small compared to the Canadian and CIS surveys, it focuses on Europe’s largest R&D performing firms. These firms account for the majority of European R&D expenditures. Another advantage of PACE is that it sampled at the line of business level for large firms that are active in several types of products. Results are available for 58 food divisions from 38 firms, 5 agro-chemical (ISIC 2421) divisions, and 5 seed divisions. These are combined for analysis into one agro-chem group.

One PACE question is of relevance to PITA. Respondents were asked about the importance of environmental regulations in Europe as an obstacle to the ability of their unit to profit from its innovations. Six response options were given: Not Applicable (if the firm did not sell products in Europe) plus a five-point subjective scale ranging from ‘not important’ to ‘extremely important’.

[55] This is partly because of differences in sample fractions and data quality between countries, which requires controlling for a range of factors in the analyses. Once this is done, there are too many empty cells to produce meaningful results.

[56] The technology classes are based on the system used in the OECD report *Technology, Productivity and Job Creation*, OECD, Paris, 1996.

APPENDIX II : Theory Of Innovation And Employment

The importance attributed by policy makers to innovation as a solution to unemployment is not matched by an equivalent body of economic research on this issue. This is partly explained by the difficulty in estimating the employment effects of innovation[57]. Innovation is a micro-economic phenomenon that occurs at the level of the firm while employment is a macro-economic phenomenon that occurs at the level of an entire economy. A full assessment of the links between employment and innovation would require tracing the effects of an innovation throughout the entire production chain. This requires complete data on both innovation at the firm level and employment data at the level of a sector or an entire economy. This type of data is seldom available, although the 1993 and 1997 Community Innovation Surveys (CIS) provide a first step in this direction.

The lack of concrete research results for the employment effects of innovation extends to several recent policy studies on innovation and employment. For example, the OECD (1996) report *Technology, Productivity and Job Creation* discusses how innovation influences employment, but the study does not provide detailed empirical evidence for the linkages between technical innovation and employment. A report for the European Commission by a High Level Expert Group (HLEG, 1997) discusses the effect of information and communication technologies on the organisation of work, but there is no discussion of employment impacts, other than a brief comment that information technology will provide 'opportunities for new forms of employment in high value, high skill occupations'. Similarly, a report on environment and employment notes that there are very few empirical studies on the effect of environmental policy or innovation in clean production technologies on employment (Gameson *et al*, 1997). One exception is a recent study by Passamonti and Lucchi (1998) for the FAIR project, which is funded by the European Commission. This study used basic data on current employment in electronic commerce and the traditional retail sectors to estimate the effect of electronic commerce on future employment in the European Union. Another is a recent study by Arundel and Rose (1999) on the employment effects of environmental biotechnology.

How innovation influences employment

The effect of innovation on employment depends on three factors: the type of innovation, direct and indirect effects in firms within the value-added chain, and compensatory mechanisms that can reduce the tendency for process innovation to reduce employment.

Type of Innovation

There are two main types of innovations:

- Product innovations that improve existing products or create entirely new products, and
- Process innovations that reduce inputs of labour or materials for existing products.

In addition, some innovations influence both manufacturing processes and product characteristics, such as process innovations that improve product quality. The employment effects of both product and process innovation depend on the unit of study within the economy, which includes the firm, the sector, or the entire economy (Schettkat and Wagner, 1990).

Product innovation is generally viewed by economists as having a positive effect on employment, but this depends on the type of product innovation. Some product innovations provide a better substitute for an existing product. The effect on overall employment depends on the rate of job loss in the firm or industry that produces the original product compared to

[57] Other explanations include the focus of economic research on other employment issues, such as the distribution of wages, and the widespread use of equilibrium models which assume full employment.

the rate of job gains in the innovative firm or industry. Other product innovations produce completely new products. This is usually thought to increase employment, although this depends on a growth in consumer spending. Most empirical research on the effect of product innovation on employment has not separated product innovation into its two components.

Process innovation often reduces inputs of labour or materials and consequently acts to reduce employment at the level of the sector or economy, although it can improve the competitiveness of the firm that introduces the process innovation, leading to expanded sales and an increase in employment (Miles, 1990). It is also possible for process innovations to increase employment at the sectoral level if there are compensatory effects through price or trade mechanisms. Process innovation to improve quality could also increase demand, thereby leading to an increase in employment.

Direct and indirect employment effects

Product and process innovations can have *direct* and *indirect* effects on employment. Direct effects occur within the firm that markets a product innovation or within a firm that uses a process innovation. For example, a firm that develops a new variety of corn that is resistant to the corn borer can experience a direct increase in employment due to an increase in demand for its corn seed. Indirect effects occur within upstream suppliers, competitors, and among downstream users. The possible indirect effects of the resistant corn seed include declines in employment among agrochemical firms that manufacture insecticides for corn weevils, firms that supply chemical feedstock to agrochemical firms, and competitors in the corn seed market. In some cases the indirect effects can occur within the innovative firm itself, with one business unit of a large multidivisional firm developing an innovation that influences employment levels in another division (Ewers et al, 1990).

Compensatory mechanisms

There are two main compensatory mechanisms for a decline in employment from process innovation or from product innovations that replace existing products. First, sectoral employment can increase if cost savings are reflected in a decline in the price of the product and if the elasticity of demand is favourable, such that a fall in the price leads to an increase in demand that is met through expanded production and employment. Second, lower prices could either replace imports or increase exports. In this case, employment loss is shifted to a different country. A third compensatory effect, although one that is difficult to trace, is due to higher wages in the innovative firm or industry (from a growth in productivity) leading to an increase in consumer demand. A similar compensatory effect is due to higher consumer demand as a result of consumers spending their savings, from lower prices, elsewhere in the economy. Passamonti and Lucchi (1998) use an income-consumption analysis to estimate the latter effect from the use of electronic commerce. They report that almost all of the estimated employment gains for this technology are from a savings-related increase in consumer purchases of other goods and services.

Empirical evidence

The available studies of the effect of product and process innovation during the early 1990s *at the firm level* in Germany, the Netherlands, France, Italy and Austria generally show that product innovation *increases* employment in the innovating firm. As an example, Brouwer *et al* (1993) examine employment growth in a panel of 771 Dutch firms between 1983 and 1989. They report a positive correlation between employment growth and the relative effort expended by a firm on product compared to process innovation. They suggest that this effect could be partly explained by product life cycle factors. Firms that expend a lot of effort on product innovation could be active in new products where both markets and employment are likely to grow.

The results at the level of the firm for process innovation are less consistent. Process innovation increased firm level employment in the Netherlands (Licht, 1997), Germany (Smolny, 1998) and France (Greenan and Guellec, 1997), but decreased employment in a separate study for Germany (Licht, 1997) and in Austria (Leo and Steiner, 1997) and Italy (Cesaratto and Stirati, (1997). Other results for Italy from the early 1980s show that more firms report a decrease than an increase in employment after the introduction of an innovation, but that the most frequent outcome is no change in labour requirements (Pianta et al, 1996). Blanchflower and Burgess (1998) found the introduction of new equipment (essentially a process innovation) to increase employment in the UK and Australia. They caution that the results show the opposite effect when they are unadjusted for firm size[58].

Only a few studies have estimated the effect of innovation on employment at the level of a sector or economy. Guellec and Greenan (1997) found process innovation to decrease employment in France at the industry level, as expected.

One of the most thorough studies of the effect of innovation on employment models the direct and indirect employment effects of the adoption of industrial robots in Germany (Edler, 1990). The direct effects include employment levels among robot manufacturers and users in the car industry. The indirect effects include suppliers to the robot manufacturers and suppliers to the car industry. The results show an overall decline in employment with the adoption of industrial robots. The introduction of compensatory effects through a reduction in price and a demand elasticity of 1 leads to lower employment losses, but the net effect is still a decline in employment[59]. This latter result is directly relevant to innovation in the agrochemical and agro-biotechnology sectors, since it is unlikely that the elasticity for final consumer demand for food products exceeds–or even approaches–1.

Figure 1 in this appendix illustrates the linkages between policy, innovation, and employment. The figure includes the effect on employment of the location of investment. One concern is that unfavourable policies or public hostility to biotechnology could cause firms to locate R&D, manufacturing or other functions outside of the EU. Compensatory effects can show up through trade and consumer demand. The final row of Figure 1 summarises the main indirect effects on suppliers and competitors. In addition, innovations that are used as inputs by other firms can affect employment levels in these user firms.

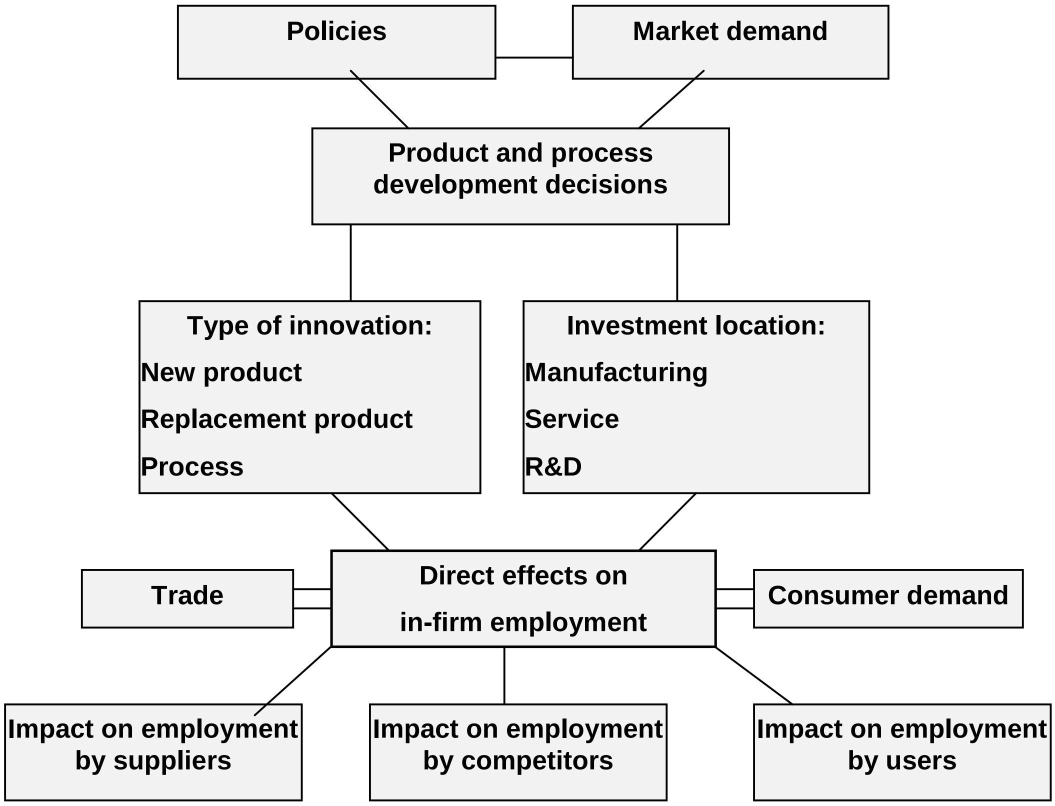
Effect of innovation policy on employment

We are not aware of any studies that have directly evaluated the potential employment effects of different policy options to support commercial innovation. However, there is an extensive literature on the effect of environmental regulation on employment and on other factors that are indirectly linked to employment, such as competitiveness, trade, and the location of manufacturing facilities.

The motivation for much of this literature is to determine the economic effects of strict environmental regulation. One possibility is that regulation could be designed to promote process innovations that use less energy and materials (Pearce and Turner, 1984; Porter, 1990). This could “trigger innovation that may partially or more than fully offset the costs of complying with them” (Porter and van der Linde,1995, p 98). If successful, such regulation would lead to employment losses (assuming no compensatory effects), since the savings would be due to a reduction in either direct labour needs within the user firm or indirect labour needs by suppliers of energy or material inputs. However, this scenario is referred to as a “win-win” situation because of gains for both the environment and the competitiveness of firms.

[58] For example, assume that a sector contains 10 firms with 20 employees and 1 firm with 1000 employees. All introduce the same process innovation. The 20 small firms report a 5% increase each in employment while the large firm reports a 2% decrease in employment. An analysis that is unadjusted for firm size will show that the process innovation increased employment in over 90% of the firms, while a industry level or size adjusted analysis will show a net decline in employment.

[59] The elasticity is 1 when demand increases by the same percentage as the decline in price. For example, the elasticity is 1 when a 10% decline in price leads to a 10% increase in demand. For many products, demand elasitcity is less than 1, as when a 25% decrease in price only increases demand by 10%. A possible exception is many services, which are believed to be ‘superior’ goods. Here, demand elasticities can exceed 1, such that a 10% decrease in price (or consumer income) results in more than a 10% increase in demand.



Appendix II – Figure 1 Policy, innovation and employment

A review of the effect of environmental regulation on the competitiveness of American manufacturing found little evidence to indicate that these regulations adversely influenced the location of manufacturing plants or competitiveness, but this is partly because the amount spent to meet regulation is low in most industries and is therefore unlikely to be a significant competitive factor (Jaffe et al, 1995). Similarly, Tobey (1990) found no evidence to indicate that domestic environmental policies influenced trade patterns. Both of these results suggest that regulation has not caused firms to move manufacturing off-shore or to lose market share to foreign competitors.

Golombek and Raknerud (1997) determined the effects of strict versus weak environmental regulation on manufacturing employment in Norway in three sectors: pulp and paper (PP), steel and ferroalloys (SF), and basic industrial chemicals. Strictly regulated firms in PP and SF had *greater* employment growth than weakly regulated firms.

ZEW (1999) used case studies and a telephone survey of German firms to evaluate the direct and indirect employment effects of adopting end-of-pipe and integrated environmental technologies. They found a slight increase in employment, while between 80% and 90% of the respondent firms reported no change in employment levels. However, the study did not fully trace all possible effects, such as a decline in competitiveness due to higher costs.

These results are of value to estimates of the employment effects of policies to support sustainable agriculture because they show first, that competitiveness is not necessarily reduced by strict regulation, and second, that 'win-win' environmental regulation can often reduce employment. This is because of a trade-off between competitiveness and employment: the former is unlikely to be maintained *unless* firms can reduce inputs, which will lead to employment losses somewhere within the production chain. The conflicting results for Norway, where employment levels rose in more strictly regulated firms, could be due to compensatory effects, such as an increase in either domestic or foreign demand. The slight increase in employment for Germany could result in a small decline in competitiveness.

Innovation and employment skills

Innovation, particularly through process changes, has long been thought to reduce skill requirements. Examples are Taylorism and Fordism, where organisational and technical changes to production methods reduced the skills needed to assemble products. In contrast, recent technical innovations such as the application of information and communication technologies tend to favour skilled over unskilled labour (Cotis et al, 1996; Siegal, 1998; Hall, 1998).

Whether or not innovation strategies are biased towards skilled or unskilled labour is an important issue for employment because of its link with wages and the supply of skilled workers. Traditionally, skilled labour has been paid above average wages. This has led to a policy preference to support innovation on the basis that it will lead, if not to more employment, at least to higher paid employment. This policy prescription is not likely to be entirely reliable because of a breakdown in the positive relationship between high skills and high wages in countries, such as France, with an oversupply of educated workers (Goux, 1996). In addition, the relationship between wages and skills will depend on other factors such as worker productivity and shortages of some highly desirable skills. These can vary by sector and by the development path of future innovations.

Other factors influencing employment estimates

Several factors that are not directly linked to innovation can bias empirical research on employment effects. Two factors that are relatively well-understood, although difficult to control, are outsourcing and job turbulence.

Outsourcing is a problem when inputs that are normally obtained from either the same firm or from a different firm in the same sector are obtained from firms in completely different sectors. An example is the rapid increase in business services, partly due to a shift in the location of employment in manufacturing support services from manufacturing firms to service firms. Although the total number of jobs that are linked to manufacturing could remain unchanged, the movement of jobs to business service firms results in an apparent decline in manufacturing employment. One estimate is that a substantial fraction of the decline in employment in France between 1977 and 1992 in the office equipment sector was due to an increase in inputs from the service sector (Meijers, 1997).

Outsourcing is also of direct relevance to employment estimates for the agricultural biotechnology sector. This is because firms that do not sell products are classified in services rather than in the goods producing sectors. For example, an agro-biotechnology firm that develops new seed varieties, but which does not produce and sell the varieties itself, is classified as a service firm.

Second, estimates of employment changes due to innovation are complicated by high levels of job turbulence, or the percentage of total jobs that are created and destroyed in a year. For example, research in Canada shows that 10 jobs are shuffled for every net increase in one job (Hamdani, 1997), due to job loss in some firms and job creation by other firms. Similarly, Klette and Mathiassen (1996) find that the movement of jobs from declining to expanding manufacturing sectors is only a small fraction of the total amount of job creation and destruction in Norway. There is also some evidence to suggest that high rates of job turbulence are linked to net job growth (Konings, 1995; Bellman and Boeri, 1998), although Davis and Haltiwanger (1992) report a negative correlation between net employment growth and job turbulence in the US between 1976 and 1982.

Innovative intensity and employment growth

One expectation is that employment growth will be positively correlated with the innovative intensity of a firm. This should occur for both product and process innovation, since process innovators should be able to win market share away from their competitors. Surprisingly, this expectation is not always supported by empirical research at the firm level.

Brouwer *et al* (1993) find that employment growth is not correlated with firm's R&D intensity, which is one measure of the innovative activity of a firm. Klette and Forre (1998), in a study of Norwegian manufacturing plants between 1982 and 1992, report that there is no link between net job creation and R&D intensity. In fact, they find that plants that do not perform R&D have higher job creation rates in all years than R&D performers.

At the macro-economic level, Aghion and Howitt (1994) develop a model for the link between economic growth and employment. Economic growth occurs through innovation, which results in the destruction of older manufacturing plants. Moderate levels of innovation produce a higher natural rate of unemployment than no innovation, due to increased job turnover from a decline in the length of each job and a time delay between the loss of a job and the acquisition of a new one. However, very high rates of innovation can reduce the natural unemployment rate, producing an inverted 'U' relationship between natural unemployment and innovation rates.

Appendix III : Survey Tables and Questionnaires

Apppendix III Table 1 Fax and follow-up protocol for the PITA questionnaire survey

	Days after first fax
First fax	0
Reminder fax including another copy of the questionnaire	10 –14
First telephone reminder call	28 – 35
Second telephone reminder call	40

Appendix III Table 2 The use of plant breeding technologies by firm size

Employees	N	Only uses classical plant breeding techniques	Uses classical plant breeding assisted by more advanced biotechnology	Uses genetic engineering	
< 35	36	67%	17%	17%	100%
35 – 99	31	52%	29%	19%	100%
> 100	32	9%	25%	66%	100%
All firms[1]	*99*	*43%*	*23%*	*33%*	*100%*

Appendix III Table 3 Changes in the direction of the crop development budget for all firms that develop new seed and crop varieties

	Development technology					
Direction of Change	Genetic engineering		Assisted conventional		Conventional	
	% Firms	% Employees	% Firms	% Employees	% Firms	% Employees
Current users of genetic engineering only (33 firms)						
Decrease	10	7	10	7	71	86
No change	35	21	23	15	26	9
Increase	55	72	68	78	3	5
Current users of assisted conventional breeding (23 firms)						
Decrease	–	–	4	2	78	88
No change	70	51	17	10	22	12
Increase	30	49	78	88	0	0
Current users of conventional breeding only (43 firms)						
Decrease	–	–	–	–	55	61
No change	77	67	50	45	45	39
Increase	23	33	50	55	0	0

Appendix III Table 4 Pearson correlation coefficients[1] for the expected % increase in technology use by the % change in development employees (p values in parentheses)

	Percentage change in technology:		
	Genetic engineering (31 users)	**Assisted conventional (50 users)**	**Conventional (87 users)**
Current users of the technology[2]	.035	.091	.071
	(.78)	(.44)	(.51)
Current non-users of the technology[3]	-.028	.103	.10
	(.61)	(.36)	(.37)

1: All results employment weighted, with the weighting normalised to the number of firms.

2: (planned use – current use)/current use; set to zero when numerator = 0.

3: Since current use is always zero, the correlation is with the percent of planned use.

ANNEX F1

Your firm' refers to operations in [the Netherlands] only. DO NOT include subsidiaries or parent firms located outside of [the Netherlands]

1. Does your firm develop or improve agricultural seed or plant varieties?

Yes ☐	No: Only market varieties developed outside [the Netherlands] ☐
(Go to question 2)	No: Only field test varieties in [the Netherlands] ☐
	No: Not involved in agricultural crop varieties ☐
	(If no, please go to question 4)

2. Does your firm use the following technologies to develop these varieties?

(Please tick (✓) all technologies currently used by your firm)

1. Genetic-engineering (insertion of new genes using rDNA technology)	☐
2. Classical plant breeding assisted by DNA markers, sequencing, or amplification	☐
3. Other (classical plant breeding without using DNA markers, etc)	☐

3. Approximately how is your firm's crop development budget divided among these technologies today? What are your expectations for three years from now?

	Today	**In three years**
1. Genetic-engineering	................%	................%
2. Classical plant breeding assisted by DNA markers, etc	................%	................%
3. Other	................%	................%
	100%	**100%**

4. How many employees does your firm currently have in [the Netherlands]?	....
What percentage of your employees are involved in developing or field testing agricultural seed or plant varieties? *(Include relevant employment in research, field Testing, regulatory compliance, & management)*	**.............. %**
In three years, by what percentage do you expect the number of your employees involved in developing or testing plant varieties to change? *(please note if positive or negative)*	.... %

6. What were your firm's worldwide *sales* in 1998 from seed and plant varieties produced in [the Netherlands] ?	............................'000 NLG
Approximate percentage of these sales in **EU** countries	**..................%**
Approximate percentage of these sales in **Non EU** countries	**..................%**
	100%

When completed, please fax this page only to..

ANNEX F1

[*reference code*]

'Your firm' refers to operations in [the Netherlands] only. DO NOT include subsidiaries or parent firms located outside of [the Netherlands]

1. Does your firm develop new or improved agricultural pesticides?

(Please check all that apply)

☐ Chemical pesticides
☐ Bio-pesticides
☐ Specific pesticide/crop combinations (ie. herbicide tolerant crop varieties)

☐ No: Only market pesticides developed outside [the Netherlands]
☐ No: Do not develop agricultural pesticides
(If no, please go to question 4)

3. Approximately how is your firm's pesticide development budget divided among the following technologies today? What are your expectations for three years from now?

	Today	**In three years**
1. Chemical pesticides	................%	................%
2. Bio-pesticides	................%	................%
3. Pesticide/crop combinations (including development of the crop plant variety, if relevant)	................%	................%
	100%	**100%**

4. How many employees, in total, does your firm have in [the Netherlands]? ....

How many of these employees are involved in developing pesticides?
(Include relevant employment in research, trials, & management) **................**

In three years, by what percentage do you expect the number of employees involved in developing pesticides to change? *(please note if positive or negative)* **...............%**

5. What were your firm's worldwide *sales* in 1998 from pesticides produced in [the Netherlands]? ....'000 NLG

Approximate percentage of these sales in **EU** countries **..................%**
Approximate percentage of these sales in **Non EU** countries **..................%**
100%

When completed, please fax this page only to ..

ABBREVIATIONS

CIS	Community Innovation Survey
EU	European Union
HT	Herbicide tolerance
GM	Genetically modified
GMO	Genetically modified organism
IPR	Intellectual property rights
JRC	Joint Research Commission
PPP	Plant protection products
SNIF	Summary notification information format
USD	United States Dollar