Unclassified **AGR/CA/APM(2000)5/FINAL**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

OLIS : 19-Dec-2000
Dist. : 20-Dec-2000

Or. Eng.

DIRECTORATE FOR FOOD, AGRICULTURE AND FISHERIES
COMMITTEE FOR AGRICULTURE

AGR/CA/APM(2000)5/FINAL
Unclassified

Working Party on Agricultural Policies and Markets

MODERN BIOTECHNOLOGY AND AGRICULTURAL MARKETS: A DISCUSSION OF SELECTED ISSUES

This is the final version of a study which was carried out under the 1999/2000 Programme of Work of the Committee for Agriculture.

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FOREWORD

This is the final version of a study which was carried out under the 1999/2000 Programme of Work of the Committee for Agriculture. The principal author was Linda Fulponi. Other staff in the Directorate for Food, Agriculture and Fisheries also contributed.

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MODERN BIOTECHNOLOGY AND AGRICULTURAL MARKETS: A DISCUSSION OF SELECTED ISSUES

Introduction

1. Over the past decade the OECD has contributed to international discussions on environmental and consumer safety issues of modern biotechnology in agriculture.[1,2] In light of the ongoing debate both within and between OECD Member countries on modern agricultural biotechnology, a synthesis of the main economic issues was prepared. Its purpose is to provide an overview of the issues that may affect agricultural markets using information currently available from a wide range of studies. As more information is made available, additional studies of the major themes presented here may need to be undertaken to assess more specific economic and social implications of what some call a second green revolution.

2. The application of modern biotechnology to agriculture has been underway for over 15 years, though discussion on genetically engineered foods has intensified within many countries more recently.[3] The debate on the benefits and possible risks of the use of genetic engineering in food production is often emotionally laden even when both asides are assuredly objective. This might be expected, as food is not only essential to life, but for many it also expresses cultural, religious and even political visions of society. There are those who recognise the potential benefits of agricultural biotechnology to society and advocate its rapid development and dissemination. Others urge the adoption of a slower, more cautious strategy, moving forward only as knowledge accumulates.

3. Among the many issues arising from the use of genetic engineering in agriculture are consumer concerns about possible adverse effects on human and animal health and the impacts on the environment particularly in the long term. For some there are also ethical concerns, regarding genetic manipulation. No peer-reviewed scientific literature has given evidence that genetically engineered foods have adverse effects on human health, yet there remains uncertainty about the potential long-term effects of GM food on human health (OECD,2000)). The OECD report on Novel Foods and Feeds acknowledged that there are differences among countries concerning the approaches to the detection of possible long term effects through post-market surveillance (OECD, 2000). In many countries consumers are reticent towards consuming genetically engineered products and are obliging public authorities to engage in more open, transparent and inclusive policy discussions concerning their regulatory framework, including testing and

1 . The working Group on the Harmonisation of Regulatory Oversight in Biotechnology has focused on environmental safety concerns of genetically modified (GM) foods (OECD, 1993a). And the Task Force on the Safety of Novel Foods and Feeds, complementary to the Working Group identifies critical nutrients and toxicants in specific GM plant varieties. Another OECD area of work is the Co-operative Research Programme, whose aim is to intensify fundamental research in biotechnology and to incorporate research that integrates socio-economic and scientific concerns as well as risk assessment. See http://www.oecd.org/agr/prog. The purpose of the OECD Seed Certification Schemes is to harmonise the assessment and certification of identity and purity of cultivar varieties including genetically modified ones. Its future work is to address certification aspects of GM varieties entering international trade. A wide range of studies have also been undertaken in the different OECD directorates, ranging from intellectual property rights to the status of research and development of agricultural biotechnology for developing countries. See http://www.oecd.org/ehs/icgb/.

2 . Recently, due to public interest in the role of modern biotechnology for food production, the G-8 requested that the OECD "undertake a study of the implications of biotechnology and other aspects of food safety". These reports have been submitted to the G8 and can be found on http://www.oecd.org/subject/biotech. They include: a summary of the Consultation with Non-Governmental Organisations (NGOs). November, 1999), the Chairman's Report and Rapporteurs' summaries of the Edinburgh Conference on the Safety of GM foods (February 2000) as well as the main reports of the Ad-hoc Group on Food Safety, the Task force for the Safety of Novel Foods and Feeds and the Working Group on the Harmonisation of Regulatory Oversight in Biotechnology.

3 The terms genetically genetically engineered and transgenic are, for the present discussion, used synonymously.

evaluation protocols. Growing market concentration in the seed and ago-chemical industries, which have, in many cases, also begun to co-ordinate their activities with the downstream agro-food industries have generated some apprehension among farmer groups in a number of countries. (Appendix 1 discusses this issue briefly). Concentration in agricultural biotechnology research and development (R&D) in a limited number of firms is also of concern to producers and consumers in OECD member and non-member countries. This is due not only to their increasing market power but also to their control of the knowledge base through proprietary instruments, such as patents. These instruments are however, granted for only a limited time period (20 years from the date of filing), after which the invention enters the public domain and may be freely accessed by anyone. Thus, over time, patents, not only provide economic incentives for continued research and innovation but also aid in the dissemination of knowledge. Indeed, the role of intellectual property rights with respect to genetically engineered products, in the context of an international trading framework, has raised a number of policy issues not easily resolved.

4. A number of benefits are expected from the use of modern biotechnology methods in agriculture. These include: the decreased use of pesticides from modifying agronomic traits, higher yields from reduced crop losses and more productive animals. Foods with specific quality traits such as improved nutritional content or disease resistance could also benefit consumers in the future. Furthermore, world population is continuing to grow at the rate of about 160 persons per minute and is expected to reach 9-10 billion by the year 2050, with almost 90 per cent of the world's population expected to be living in developing countries[4] (Federoff and Cohen, 1999). If as in the past food continues to be consumed where it is produced, then 90 per cent of the increase in food demand must be grown in farming systems where population is most rapidly increasing. It is suggested that the advances in crop genetic engineering may, within another decade, have the potential to help meet increased food demand and if prudently employed, to also promote sustainable use of natural resources for the more fragile regions[5] (Evenson, 1999, Ruttan, 1999).

5. The subject matter of modern agricultural biotechnology is very wide and diverse, thus the paper focuses only on a limited number of topics and products derived from this technology.[6] This paper attempts to synthesise some of the main economic issues that are of importance to selected agricultural commodity markets arising from the use of modern agricultural biotechnology. Maize, soybean, cotton and rBST are the examples of genetically engineered products discussed in the paper. Attention is focussed on the supply side issues, that is, farmer adoption and assessment of benefits. Demand side issues such as, consumer concerns and labelling are also briefly examined. The paper is organised as follows: Part I provides general information on modern biotechnology developments and issues. It then reviews the findings on adoption of genetically engineered crop varieties and rBST and their economic benefits; Part 2 summarises selected demand side issues including consumer concerns, labelling and market implications; finally Part 3 provides a brief conclusion.

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4. Most of the world population increase is expected in tropical countries. At present poverty is the key constraint for meeting nutritional requirements. Over 1.2 billion persons live on less than USD 1 per day and another 1.6 billion on less than USD 2 per day, this level of poverty afflicts about 30 per cent of the world's population. It implies very low purchasing power for inputs as well as imports.

5. For instance, research efforts are being made to engineer crops to require less water, thus making them suitable for arid regions or to be tolerant to salt so as to be farmed in salt-damaged farmland or irrigated with salty water (Tsaftarias et al, 1999).

6. The use of genetic engineering for farm animal improvement is excluded from the discussion, though it is recognised that issues posed by their development will likely differ from those dealing with plants. As these are not yet commercialised, these may be considered in future work.

Part 1. Modern Agricultural Biotechnology

A. General Issues

> **Definitions:**
>
> ***Modern agricultural biotechnology*** *is the application of cellular and molecular biology to diverse agricultural production processes and products. One important aspect of this new agricultural biotechnology is in the breeding of new plant varieties as well as specialised micro-organisms through genetic engineering(GE) .*
>
> ***Genetic engineering*** *refers to a set of technologies that artificially move functional genes across species boundaries to produce novel organisms as well as to suppress or enhance gene functioning in the same species.*
>
> ***Insect resistant-Bt crops*** *are engineered so as to contain a gene from the soil bacterium Bacillus thurigiensis that is specifically toxic to certain insect pests .*
>
> ***Herbicide resistant-HR-crops*** *are genetically engineered to resist specific herbicides.*
>
> ***Recombinant bovine somatotropin-rBST*** *is a genetically engineered version of a naturally occurring hormone, which stimulates milk*

6. At present several basic commodities dominate the market for genetically engineered crops: soybeans, maize, cotton, canola and potatoes. The most widely planted genetically engineered crops concern only one agronomic trait, though a few varieties incorporate two traits. Maize and cotton as well as potatoes are modified to be insect resistant, while soybean and canola are modified to withstand specific herbicides. Certain varieties of maize and cotton carry both herbicide and insect resistant traits. Virus resistance is the other main agronomic trait applied to crops and is used in genetically engineered tobacco, tomatoes and potatoes. Genetic engineering is also used to produce a synthetic bovine growth hormone (rBST) to stimulate milk production in cows. Other genetically engineered products are used in agriculture and food production, such as chymosin, an enzyme for cheese production and certain animal vaccines.

7. The ‘first generation’ of genetically engineered crops focuses on agronomic traits to reduce crop losses due to pests and to reduce pesticide use or in the case of rBST, to stimulate milk production. With respect to crops, due to expected lower pesticide use and constant or better yields, these varieties should increase farmers’ profits.[7] They are also expected to decrease many of the detrimental environmental consequences of pesticide use, through the use of less harmful active ingredients as well as overall reductions in active ingredients. This environmental externality of genetically engineered crops can provide important benefits to society as a whole. The possibilities for adapting crops to specific climatic, agronomic and pest conditions could provide important benefits for agriculture in many developing countries, where pests (disease, weeds and insects) often reduce potential crop production by 50 per cent or more[8] (Oerke *et al.*, 1995; Yudelman *et al.*, 1998). Where population growth continues to be rapid, this

7 . This assumes that output prices do not decrease.

8 . Knowledge of actual crop losses due to pests (disease, weeds and insects) is inadequate and estimates vary from 10-15 per cent to over 50 per cent. A comprehensive study, based on 8 crops, estimated the economic loss in terms of production potential (actual production plus total estimated losses) from pests. It found that in 1988-1990 losses were approximately USD 300billon, that is about 70 of world production. And the study did not cover millet, sorghum or cassava important to developing countries. The study further noted that the largest losses were for wheat and rice, two key developing country food crops. Thus it is likely that the potential production losses from pests in monetary terms are even higher than the USD 300 billion.

technology could contribute to meeting the food needs within the country, though it is not necessarily the only or main solution to the problem. Box 1 provides a brief summary of selected aspects of this issue.

Box 1. Modern Agricultural Biotechnology and Developing Countries Food Needs

With 90 per cent of world population increase occurring in developing countries, food demand will put pressure on the agricultural ecology of the major staple crop systems in these countries (Federoff and Cohen, 1999, McCalla and Brown, 2000). About 55 per cent of this increase is expected in those countries whose resource bases are most fragile. At present, most of these countries rely on their own production to meet their food needs, but food production may be becoming more variable with the ensuing negative impacts on the livelihood and nutrition of these populations. Increased urban demand for foodstuffs will also increase pressures on the agricultural resource base. By the year 2025, demand for cereals could reach 3 billion tonnes requiring average yields of about 4 tonnes per hectare compared to present yields of about 3 tonnes per hectare (Dyson, 1999). Will world farmers meet this need? Many researchers say yes, as they believe yields will continue to increase. Because available arable land and water in agriculture are diminishing, there is no option but to produce more food through intensive agriculture by raising yields per unit of land, labour and inputs. Given the large proportion of agricultural production lost to pests and disease, higher yields might be achieved by reducing these losses. Genetically engineered crop varieties, which already focus on reducing crop losses due to pests, could in principle begin to contribute to improved crop yields, if tailored to developing country crops and pests.[1]

However, the gap between farm yields and genetic potential is closing and the potential yield in crops is increasing more slowly than expected food demand. This implies that farm yields must reach 70-80 percent of yield potential, while minimising environmental degradation. To meet this challenge, major scientific breakthroughs in plant physiology, soil science and agro-ecology must occur (Cassman, 1999). However there are preliminary indications of a decline in agricultural research productivity. For instance, the scientist years of research needed to increase basic food crop yields have been rising more rapidly than yield increases as physiological constraints to increased productivity begin to bind (Ruttan, 1999). Modern agricultural biotechnology has the potential to contribute to the development of new crop varieties adapted to fragile ecosystems and to enhance yields, actual and potential. And it may be able to do so more rapidly than traditional methods as it can reduce the time needed to develop a plant variety with specific characteristics by about 40 to 50 per cent. In addition, these techniques may permit achieving desired traits, which would not be possible without the ability to transfer genetic characteristics (codes) between species (Ruttan, 1999, Cassman, 1999). For instance, two genes from maize have been inserted into rice to increase its photosynthesis capacity, now known as C_4 Rice, resulting in a 30-35 per cent yield increase in field tests (Ku *et al*, 1999). The use of genetic engineering should not be considered the only or the main approach to developing higher yielding or pest resistant plants of importance to meeting the food needs of developing countries. There, in fact, remains substantial room for the transfer of conventional agricultural technologies to developing countries to increase food production (Ruttan,1999).

Thus far most private sector advances in modern biotechnology have not been geared to the specific needs of developing country agricultural systems due to the lack of financial incentives. This may be a result of the weak international property rights guarantees and lack of purchasing power in these countries. This situation represents a market failure for which public R&D monies are justified (Serageldin, 1999; Conway1998). However, public R&D expenditures for international agricultural research have been declining despite the growing needs in developing countries.

To the extent possible, developing countries are developing their research capacity in modern biotechnology, with most of it funded by national governments (Persley and Lantin, 2000). They are focussing their biotechnology work on increasing agricultural productivity through increased pest and disease resistance. For instance, in the Philippines, research is focussing on disease resistant bananas and papaya as well as insect resistant corn and delayed fruit ripening. Already small farmers are adopting the technology where available: in Mexico virus resistant potatoes, in Kenya disease free banana plantlets, in South Africa pest resistant cotton is being planted and in Zimbabwe new GM vaccines are being used against animal disease. In China, a number of genetically engineered crop varieties, many with pest and virus resistant traits, have been approved for commercialisation (ISAAA, 2000).

Socio-economic concerns are also arising in developing countries about future possible effects of the technology. These include impacts on the increasing gap between rich and poor farmers and its impact on biodiversity as modernisation reduces food security in terms of species. The genetic homogeneity and vulnerability to biotic and abiotic stresses, particularly where regulatory guidelines and mechanisms are not yet in place can also be a major preoccupation. Attention must be given to these concerns in a preventive fashion; so as to make full use of the potential provided by the technology.

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[1] The present technological gap between the industrialised countries and developing countries implies that food production prospects could also be improved simply through efforts to adopt and diffuse advanced country technologies to these countries.

[2] The green revolution modified the fundamental structure of the plant so as to improve its capacity for photosynthesis by reducing its size and making it more efficient in its transformation of soil nutrients. As yield is determined by a number of genes it will not be an easy task even for biotechnology to alter plant yields. Only recently with the development of 'GoldenRice™' were researchers able to manipulate up to 7 genes.

8. The present set of genetically engineered products have focussed on agronomic traits which have not been perceived as delivering significant benefits to consumers compared to conventional varieties. But the modification of agronomic traits is only the beginning of the contributions of genetic engineering to modifying the food chain. Box 2 gives an indication of the products in the pipeline. The envisioned benefits of output trait GE crops could bring substantial benefits to consumers in both developed and developing countries. The choice of which innovations will go forward is likely to be determined in part by the private sector's expected profitability estimates and the legal framework, which permits countries to appropriate the return to their research. Intellectual Property Rights (IPR)or patent rights allow the patent holder to exclude all others from making, using, offering for sale, selling or importing the claimed invention for a limited time period (20 years). During this period, use of the patent requires consent of the patent holder, customarily, but not always, in return to the payment of a fee. This is an economic return to their research and provide incentives for further innovation. After the expiry of the patent, the information on which the patent was granted is available to the public. Box 3 presents a brief discussion of some of the economic issues on patent and R&D linkages.

Box 2. What is in the pipeline?

The 2nd generation of products, many of which are already developed but not yet on the market, focus on a number of traits, which will enhance their use in food production systems as well as improve their final use or quality characteristics. These include soybeans with improved animal nutritional qualities through increased protein and amino acid content. Crops with modified oils, fats and starches to improve processing and digestibility, such as, high stearate canola, low phytate or low phytic acid maize, are a few of the future products. Most of the output trait genetically engineered maize varieties are still in the pipeline, and have not reached the commercial market yet. On the industrial side, we can expect coloured cotton plants so as to avoid the need for chemical dyes (some of these plants are already available). Other products which are likely to be developed will produce more end user quality traits such as nutraceuticals or 'functional foods', which are crops engineered to produce medicines or food supplements within the plant. These could possibly provide immunity to disease or improve health characteristics of traditional foods, for instance beta-carotene canola or Vitamin A supplemented rice (Riley and Hoffman, 1999). Plants with greater nitrogen fixing capacities which reduce the need for fertilisers or plants that resist drought, flood and extreme temperatures are also envisaged as future developments as are plants which can be used for bioremediation (Oxfam, 1998). Some researchers also suggest that crops like cotton can be engineered to produce wrinkle free and/or fire resistant cotton or oilseed rape plants that produce biodegradable plastics (Riley and Hoffman, 1999). Substantial research has also been devoted to the development of genetically engineered fish, such as salmon. Genetically engineering is also been applied to animals and crops for medicinal and therapeutic purposes, such as the production of vaccines or organs. Some of these are already available for use, however many are a number of years away from generalised commercial production (Langridge, 2000,).

[1] Low phyate/ phytic acid maize reduces the need for inorganic phosphorus supplements in pork and poultry rations, thus reducing phosphorus in waste and pollution. High stearate canola and soybeans produce fats, which solidify at room temperature, facilitate food processing and are healthier for humans that present tallow used in stearates. High oleic soybean oil contains less saturated fat thus reduces food processing costs and allows longer shelf life useful for the fast-food industry. High lauric canola contains about 40 per cent lauric acid, a fatty acid used in detergents and lubricants, which is used to replace coconut and palm oil. Most of the products in the pipeline through 2002 appear essentially to carry improved agronomic traits and those useful to the food industry. Varieties of coloured cotton and high-carotenoid canola, to combat Vitamin A deficiencies as well as low calorie oils and improved-solids potatoes are in the pipeline in the post 2002 period. (Agricultural Outlook, 1999; Monsanto In the Pipeline 1998. 1999).

[2] Bioremediation is the undoing of ecological damage through the use of living, biological organisms, such as the use of micro-organisms to clean up oil spills or restoring of minerals to depleted soils.

Box 3.Intellectual Property Rights (IPR) and R&D: economic issues

The agribiotech industry is essentially a knowledge-based industry, with innovation and product development key to continued firm growth. This generates a race to develop, patent and commercialise new products. A major reason for the government to provide intellectual property rights (patents, trademarks and copyrights) protection to inventions is to create incentives that maximise the difference between the value of intellectual property that is created and used, and the social cost of its creation (Besen and Raskind, 1991,). Patents, a common form of IPR, permit patent holders to exclude others from making use, offering for sale, selling or importing the claimed invention into the country for a limited period of time. It also permits them to sell the right for payment of a fee or not to do so (Katz and Shapiro, 1985).The use of patent rights provides an economic incentive to the patent holder for further technological advances (Arrow, 1962).[1]

Most OECD countries have legal frameworks which provide protection for intellectual property rights in the field of biotechnology, though these systems vary substantially across countries (OECD, 1999a)[2]. With the change in the legal structure governing innovation in plants and animals, which essentially provides for patents for living organisms, the economic incentive for firms in R & D has been dramatically altered. The protection of new forms of life has been fraught with difficulties and wide differences remain between countries.[3] Yet a number of analysts believe that the strengthening of intellectual property law for biological materials is essential for private sector innovation as it is the only means to permit those who bear substantial investment costs to earn a fair return.

All WTO member countries must now provide either patents or effective ‘sui generis’ systems means of protection for plant varieties, according to Article 27(3) of the 1994 Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPs). Substantial freedom appears to have been granted to the development of the ‘sui generis’ systems with flexibility in their content and structure provided that the basic principles of the TRIPs agreement are met. In particular it does not prohibit additional protection systems or protection of additional subject matter, such as local knowledge systems or informal innovations (Seiler,1998, Leskein and Flitner,1998). According to the TRIPs agreement, genetic resources existing in nature would not be patentable, but only those which have been created through invention as stipulated in Article 27(2). The adoption of IPR for plant varieties ‘is expected to create incentives to innovate and add to the knowledge base’(Frey, 2000). However, the extent to which IPR does in fact generate greater rates of crop improvement are not known. Recent research has found, in the case of yield increasing varieties, that not only are profits maximised but social welfare may be increased compared to the open access case, when there are no slow down effects on innovation (Koo and Wright, 2000)..

With the advent of biotechnology and change to a stronger proprietary system, substantial basic research is now also undertaken in the private sector. Nonetheless, most R&D investment by the private sector has been for products which are patentable or marketable in the industrialised countries that can afford them. One of the central policy questions in the debate, from a social welfare perspective is: Should the government only adjust policies so as to increase private sector R&D and innovations so as to stimulate dynamic social welfare gains or should it also participate in R&D and patenting efforts? Economic theory would suggest that when the social rate of return to a project is greater than the private rate of return, public expenditure is justified in undertaking the activity. Public R&D organisations do not privately capture the financial gains of research output, but rather it is the public who do so through geographic and inter-sectoral spillovers. Measuring the social rate of return to research is however difficult, particularly where spillovers can be large and risk and uncertainty characterise the project.[4] (Evenson, 1989). Though the uncertainty portion can be evaluated as an option, the role of spillovers can be quite sizeable and the inability of firms to capture these benefits has dampened incentives to invest in certain areas. Indeed, most major advances in the biotechnology tools and knowledge systems have originated in the public sector (Caswell *et al.*, 1996; Kenney, 1986). The public sector can contribute to basic R&D and by patenting their findings ensure their dissemination to society.

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[1] Patents however raise several important policy questions:-Do firms under invest from a social welfare perspective if they cannot capture a sufficient portion of the value of the innovation?; Are innovative activities undertaken in excess of minimum social cost? (Stiglitz and Dasgupta, 1981, Schotchmer, 1991); or What is the optimal trade-off between incentives for innovation creation and innovation dissemination? (Gilbert and Shapiro, 1980).

[2] National ownership of genetic resources was first defined by the Convention on Biological Diversity(CBD) which specified that each country has sovereign rights to the plant genetic resources within its boundaries. Through IPR, countries protect not only biological inventions but also genes and cultivars, which are biological innovations. According to the TRIPS agreement, genes and cultivars may be protected by patents if they are inventions or discoveries. In the past these were ‘products of nature’ and not subject to patent law (Fuglie, *et al* , 1996). The US plant Patent Act allows patents and the Plant Variety Protection Act (PVP) provides IPR protection to the innovators (Frey, 2000)

[3] In the landmark decision of the Diamond and Chakabarty case (1980) property rights were conferred over living organisms and in 1988 over the first living animal, the Harvard mouse.

[4]It is estimated that the social rate of return to research in plant varieties is between 40 -60 per cent per year, some estimates are even higher. These rates are to be compared with rates of 18-20 per cent for other government projects. These figures would thus indicate significant under investment by the public sector (Frey, 2000; Alston *et al*., 1998).

9. Where expected profits are not a sufficient incentive for firms to undertake research to develop and market crop varieties, public research funds can provide a useful role. This may be the case for research destined to improve the micro-nutrient content and productivity of developing country food crops. It is often noted that modern agricultural biotechnology can be particularly beneficial for the developing countries, since it may provide possibilities for varietal development that could not be undertaken otherwise. See **Box 4** for a brief discussion on biotechnology and micro-nutrients for developing countries.

Box 4. Biotechnology and Micro-nutrients for Developing Countries

According to the FAO about one in 5 persons in the developing countries suffers from chronic malnutrition and about 2 billion from micro-nutrient deficiencies, with iron and vitamin A being among the most important(Levin *et al*,1995).[1] Iron deficiency is perhaps the most widespread micro-nutrient deficiency and can lead to impaired physical growth and learning capacity. A Vitamin A deficiency can lead to impaired vision and blindness. About 500,000 children become blind each year due to Vitamin A deficiencies. The economic losses from lower labour productivity or chronic illness due to malnutrition are also substantial. The World Bank (1994) estimates that deficiencies of just vitamin A, iodine and iron alone could waste 5 per cent of GDP in South Asia, but addressing them would cost less one third of 1 per cent of GDP. In India, iron deficiencies are valued at 1.25 per cent of GDP. While poverty is recognised as the major cause of the general malnutrition problem in developing countries, this problem is not likely to be solved in the near future. The issue is thus how to increase present nutritional levels under current economic constraints (Serageldin, 1999)[2].

To reduce micronutrient deficiencies, there are two options: food supplements or breeding nutrient supplements into crops. The choice between the options must be determined by which is more cost effective and has the greater probability of being accepted by the public. For example, the estimated cost of iron supplementation per year per person is USD 2.65 with administrative costs included (Levin *et al*, 1993). Treating just one half of the pregnant women in India (28million) in one year would cost about USD 37 million. Another option is that of breeding plants that enrich themselves with minerals and vitamins. This latter option provides for multiplier effects, as the initial investment may benefit millions of poor in developing countries worldwide and improve agricultural productivity. In addition, it has been found that where soil is deficient in a particular micro-nutrient, seeds containing more of that nutrient have better germination, produce more vigorous seedlings, are more resistant to infection and can result in higher yields.

What does the plant breeding strategy cost? Some indication comes from the CGIAR Micronutrients 5-year project to include iron, zinc and vitamin A in wheat, rice, maize, beans and cassava. The first phase costs of germplasm identification and general breeding techniques for all five crops are about USD 2 million per year. Bouis provides a cost benefit analysis of the use of plant breeding options and finds a USD 274 million benefit for a USD 13 million investment, giving a cost benefit ratio of about 20. This is a very high rate given the long time lag between investment and project realisation and compared to the 3-5 per cent risk free market rate, which is the usual basis for comparison. Nutrient supplement programmes must be repeated annually and are applicable to a single country, that is there are no spill over effects, while in the case of plant breeding the benefits accrue to a number of countries and do not disappear after the initial investment (Bouis, 2000).

Which technique is most cost-effective to develop new varieties, modern biotechnology or traditional breeding methods? It depends on the nutrient in question and the state of research for the crop (Bouis, 2000). For the three nutrients examined by IFPRI, iron, vitamin A and zinc it was found that for iron and zinc conventional breeding methods may give superior results. This is because a rice variety with superior consumer and agronomic characteristics, already under development at IRRI was found to be also high in iron. Thus both superior consumer and agronomic characteristics were already available and needed only moderate amounts of extra research and development (Bouis, 2000). In contrast, for beta carotene enhanced rice or 'golden rice', the transfer of the genetic code to promote vitamin A (betacarotene) production requires genetic engineering techniques. No less than 7 genes and over 20 patent licenses were involved in developing the 'GoldenR-rice™' which must now be bred into varieties adapted to the different local conditions. A balanced approach to solving the micronutrient problem for developing countries is to adapt the research strategy to the particular deficiency and crop with the appropriate cost-benefit analysis. Modern biotechnology can contribute to the solution particularly where nutrient requirements are not naturally found in food staple plants.

[1] Zinc is also considered important, though the exact requirements are not known. Iodine deficiency for about 70 per cent of the population has been remedied by adding it to salt.

[2] Micro-nutrient requirements are best satisfied through diets that include animal products or diets with a wide variety of fruits, pulses and vegetables in addition to staples (Bouis, 1999). Rice is notoriously poor in iron, yet is the staple crop in most of Asia and parts of Africa.

B. Adoption of genetically engineered varieties

10. Since genetically modified crops were first commercialised four years ago, the area harvested of these crops has risen dramatically, particularly in the United States and Latin America. Table 1 provides a summary of data on area harvested world-wide, based on industry estimates. These may differ from national statistics, but they do provide a global estimate of the use of genetically engineered varieties[9]. In 1999, the United States accounted for about 72 per cent of the total harvested area of genetically engineered crops. In Argentina, over 70 per cent of soybean and 20-25 percent of maize area harvested were estimated to be genetically modified, while in Canada, HR canola accounted for about 50 per cent of canola planted.[10]

11. Tables 2A and 2B provide information on area planted and area harvested of genetically engineered varieties in the United States according to crop type. In 1999, according to estimates from the Objective Yield Survey (OYS) of the US National Agricultural Statistical Service (NASS),Table 2B, herbicide resistant (HR) soybeans accounted for about 57 per cent of the soybean area harvested, while insect resistant (Bt) maize accounted for about 30 per cent and HR maize for 8 per cent of total maize area harvested. A small portion of maize varieties is both herbicide and insect resistant. The OYS also estimates that Bt cotton accounts for 27 per cent of area harvested and HR varieties for 38 per cent[11, 12].

12. Estimates of area planted to genetically engineered varieties for the 2000 crop year in the United States, as shown in Table 2A, indicate that about 54 per cent of the soybean area, 25 per cent of the maize area (18 to Bt varieties, 5 to HR varieties and 2 to HR-Bt stacked varieties) and 56 per cent of the cotton area (18 to Bt varieties, 22 to HR varieties and 16 to HR-Bt stacked varieties) is being planted to genetically engineered varieties. Very preliminary estimates on canola plantings also indicate that HR varieties will again account for about 50 per cent of the area planted according to the Canola Council of Canada.

13. If we examine the growth of genetically engineered crops according to their traits on a world-wide basis, we find that there has been a shift from virus resistance dominance in 1996 (China's tobacco production) to herbicide resistance which now accounts for over 60 per cent of the traits characterising genetically engineered crops, as shown in Table 3.

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9 . According to the USDA Agricultural Outlook, August 1998, in the early stages of their expansion-- 'the USDA does not make official estimates of GM crops planted…' p.21. Surveys are now undertaken to estimate area planted and harvested of GM crops. The National Agricultural Statistics Service (NASS) surveys maize cotton and soybean farmers in selected States on their use of herbicide or pest-resistant seed varieties since 1998. Randomly selected plots are visited monthly from August to harvest to obtain specific counts and measurements. NASS also publishes a Prospective Plantings report in late March that reflects a survey of farmers' planting intentions and a June Acreage report that reflects a survey of farmer's actual planted acreage taken during the beginning of June.

10 . For Canada, industry estimates are from the Canola Council of Canada. Industry estimates are used for Argentina.

11 . Economic Research Service, (1999), Genetically engineered crops for Pest Management, October 27. http://www.econ.ag.gov/whatsnew/issues/biotech/caveats.htm

12 Crop Production, October 8, 1999, Objective yield Survey, National Agricultural Statistical Service. http://usda.mannlib.cornell.edu/reports/nassr/field/pcp-bb/1999/crop1099.txt

Table 1. Area harvested world-wide of genetically engineered crops

	1996	1997	1998	1999	Share of area harvested world-wide of genetically engineered crops 1999
	million hectares				per cent
Argentina	0.1	1.4	4.3	6.7	17
Australia	< 0.03	0.05	0.1	0.1	< 1
Canada	0.1	1.3	2.8	4	10
China	1.1	1.8	n.a.	0.3	< 1
France	0	0	< 0.1	< 0.1	< 1
Mexico	0	0	< 0.1	< 0.1	< 1
Portugal	0	0	0	< 0.1	< 1
Spain	0	0	< 0.1	< 0.1	< 1
United States[1]	1.5	8.1	20.5	28.7	72
World[2]	2.8	12.8	27.8	39.9	100

Sources: James, C (1997-1999), "Global Review of Transgenic Crops", ISAAA Briefs, 1997-1999, The International Service for the Acquistion of Agri-biotech Applications (ISAAA), Ithaca, USA.

Notes:

1. The US Department of Agriculture estimates differ from the above industry estimates as follows: 1996: 3.2 million hectares; 1998: 20.23 million hectares.
2. In 1998, excludes China.

Table 2A. Area Planted - Genetically engineered crops: United States[1]

(per cent)

	1996	1997	1998	2000
HR soybean	7.4	17	44.2	54
HR maize[1]	3	4.3	18.4	7
HR cotton	-	10.5	26.2	46
BT maize	1.4	7.6	19.1	19
BT cotton	14.6	15	16.8	35

Sources :

1996-1998: Agricultural Resource Management Survey(ARMS), USDA.
2000: Prospective Plantings, March 31,2000,NASS, p.23-24.

1. Survey coverage in terms of per cent of total area planted and
and in parentheses the number of States covered in the survey.

	1996 (ARMS)	1997 (ARMS)	1998 (ARMS)	2000 (NASS)
Maize	88(16)	77(10)	89(16)	ALL
Soybeans	79(12)	93(19)	91(16)	ALL
Cotton	83(7)	96(12)	92(10)	ALL

1. 1996-1999 Includes seed obtained by traditional breeding but developed using biotechnology techniques to identify the herbicide-tolerant genes.

Table 2B. Area Harvested - Genetically engineered crops: United States[1]

(per cent)

	1998 OYS	1999 OYS
HR Soybean[1]	42	57
HR Maize[1,2]	9	8
HR Cotton[1,2]	33	39
Bt Maize[2]	25	29
Bt Cotton[2]	23	27

Source:

Objective Yield Surveys, NASS, 1998, 1999.

Notes:

1. Herbicide Resistant varieties include those developed using both biotechnology and conventional breeding techniques.
2. Includes stacked varieties. Total area harvested of GE cotton and maize varieties are not to be calculated as sum of HR and Bt varieties as these include stacked varieties and would result in double counting.
3.Survey coverage in percent of totalarea planted and in parentheses the number of States covered in the survey

	1998 OYS	1999 OYS
Maize	69(7)	69(7)
Soybean	71(8)	71(8)
Cotton	63(5)	63(5)

Table 3. Area harvested world-wide of genetically engineered crops by trait

	1996	1997 in percent	1998	1999
Herbicide tolerant	23	54	71	71
Insect resistant	37	31	28	22
Virus resistant	40	14	<0.1	<0.1
Herbicide tolerant and insect resistant	--	<1	1	7
Quality traits	<1	<1	<1	<0.1

Source: James, C (1997-1999), "Global Review of Transgenic Crops",
ISAAA Briefs, 1997-1999.

14. These area-harvested estimates reflect very high rates of technology adoption during the first years of their commercialisation and are particularly impressive when compared to that of other seed technologies, such as hybrid maize. For instance, adoption of HR soybean in the first four years exceeds that of hybrid maize adoption over the first seven years (Kalaitzandonakes, 1999). What factors explain this rapid adoption of GE crops? In the classic study of innovation in agriculture by Griliches and in subsequent studies, the most important determinant of adoption is expected profits. Other factors are also important to determining adoption behaviour, such as, farm size, demographic characteristics and educational levels of farm operators and location. [13] In models of adoption over the long run, the dynamic effects of learning on management skills and personal perceptions of the innovation are also found to be significant variables (Ghadim *et al.*, 1999). Recent surveys evaluating the reasons for farmer adoption of GE seed varieties find that increased yields through improved pest control (54-76 per cent) and the reduction in pesticide costs(19-42 per cent) to be the dominant reasons for adoption.(Fernandez-Cornejo and McBride,2000). Other reasons such as the technology's contribution to flexible crop management and ease of cultivation were also cited as important, but with less frequency: all other reasons combined ranged from 3-15 per cent. Many of these are however, often difficult to include in a simple manner in most econometric models of adoption**.**

15. It is well known that the initial adopters of a technology are those that gain the most from adoption and the latecomers often benefit little as gains from increased productivity are often eroded by the decrease in the price of the product. Perhaps farmers wishing to capture the initial rents, adopt at rates higher than seem justified by ex-post results. Cochrane (1979) in his now classic remark notes that farmers are on a technological treadmill, so that there is little choice whether to adopt or not adopt a new technology. Where innovation is proprietary, the issue of rent distribution between the different economic agents often arises. Recent studies indicate that a large portion of gains from innovation adoption accrue to the industry due to patents rights on the innovation, but results can vary according to crop. Producers and consumers also benefit (Falck-Zapeda *et al.*, 1999; Moschini *et al.*, 1999). However the distribution of welfare gains between countries and agents from adoption can vary substantially when spillover effects to other countries are incorporated (Moschini *et al*., 1999). See Box 5 for a summary of key results of both studies. Studies of adoption behaviour find that operators who adopt the genetically engineered technology are younger, more educated and already engaged in modern management practices. Adoption of modern biotechnology appears to be higher on larger farms.

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13 Dixon updated and re-estimated the original study by Griliches (1957) Dixon's results tend to confirm the importance of expected profits as the major indicator of adoption, though the importance of the variable is substantially diminished and other factors now appear more important than previously. For further discussion on the diffusion of innovation see an overview by Davidson (1994).

Box 5. Economic Welfare effects of genetically engineered crops

Many debates concerning the distribution of benefits from the introduction of genetically modified crop varieties have ensued since their commercialisation in 1996. Is it farmers, consumers or the biotech industry innovators who gain from biotech innovations? Several studies have attempted to quantitatively assess the impacts of adoption of genetically engineered crops where innovators hold intellectual property rights on the innovation, through standard measures of consumer and producer surplus as well as innovator surplus in an international trade context. Simplified versions of the world markets for cotton and soybeans are used to examine the impacts of adoption of two main genetically engineered crops, Bt cotton and Roundup Ready soybeans. Both models are based on the analytical framework developed to measure the impacts of innovation adoption where the implications of intellectual property rights (IPR), held by a multinational firm are explicitly modelled (Moschini and Lapan, 1999; Moschini *et al.*, 1999). In both cases the models are calibrated to available market information, with model parameters taken from the literature.

Bt cotton

The impacts of introducing the pest resistant Bt cotton are analysed in a two country framework, the United States and a rest of the world aggregate with no technological spillover effects (Falck-Zepeda *et al*, 1999). With constant marginal costs for conventional and genetically modified varieties, the introduction of Bt cotton increases world economic surplus by USD 240 million. Of this total the largest share went to U.S. farmers with 59 per cent, the innovator, Monsanto, received 21 per cent, U.S. consumers 9 per cent, the rest of the world 6 per cent and the germplasm supplier, Delta and Pineland, 5 per cent. These results find that innovators receive only a modest share of the gains. The authors suggest this may be due to Monsanto's decision to maintain a single low price policy rather than to price discriminate based on the regional marginal value product. Nonetheless the authors note that the size and distribution of benefits will change as Bt cotton is more widely diffused in the US and in other countries and as substitute technologies appear.

Roundup Ready soybeans

The effects of Roundup Ready (RR) soybean adoption for production, prices and welfare are examined in a three-region world model for the soybean complex: US, South America and the Rest of the World (ROW) (Moschini *et al*.1999). The model finds that the US captures the largest share of welfare gains, with the innovator capturing the greater part of these gains. In this scenario, calibrated on recent data, the increase in world welfare is about USD 804million. About 45 per cent is captured by the innovator and US producers gain about 20 per cent, the ROW consumers about 25 per cent, though ROW producers lose about 7 percent. With technology spillovers to regions, which compete in production, the share of the home country's overall welfare declines because the competitive position of producers is reduced. However, due to the monopolist profits accruing to the home country, its position in terms of welfare gains improves. With a 100 per cent adoption across all regions, about 70 per cent of efficiency gains in the US accrue to the innovator, nonetheless gains are substantial for producers in the rest of the world and consumers in all three regions. The experiment also finds that if the yields are positively affected by RR adoption, then the impact of RR adoption will significantly affect the size and distribution of welfare gains. For instance a 5 per cent increase in yields decreases total welfare gains from adoption compared to the no yield change scenario. In this case the mix of welfare gains also changes, increasing for consumers but decreasing for producers. Other key parameters are examined for their effects on welfare, such as a change in pricing strategies of the innovator and changes in cost reductions.

Sources: Falck-Zapeda, J.B., G. Traxler and R. Nelson, (2000), "Surplus Distribution from the Introduction of a Biotechnology Innovation", American Journal of Agricultural Economics, 82(May):360-369.

Moschini, G.,H. Lapan and A. Sobolevsky, (2000), " Roundup Ready Soybeans and Welfare Effects in the Soybean Complex", Agribusiness, 16"33-55.

Moschini, G. and H. Lapan, (1997) "Intellectual Property Rights and the Welfare Effects of Agricultural R&D" , American Journal of Agricultural Economics, 79: 1229-1242.

C. Preliminary Assessment of Producer Benefits of Modern Biotechnology.

16. This section reviews the preliminary economic assessments of adopting genetically engineered crops and recombinant Bovine somatotropin (rBST). As the United States is the major producer of an array of genetically engineered crops as well as the main user of rBST in the dairy industry, the focus is on the US experience. When available, studies on other countries are also included. To ensure the confidentiality of farm level data, it was not possible for the Secretariat to undertake micro level analysis of the data from

the NASS, thus this study relies mainly on published information. Empirical analyses of the economic impacts of adopting genetically engineered varieties compared to conventional ones must be interpreted with the appropriate caveats, given the limited number of observations.

While general or definite conclusions can not yet be made, available information on pesticide use, cost and yields for genetically engineered soybeans, canola, cotton and maize as well as on rBST can provide preliminary indications of their economic performance. These are examined in the following section.[14] It should also be noted that available studies concerning profitability from the use of genetic engineering in agriculture do not report their results in a homogeneous fashion, in particular, not all compare the profitability of genetically engineered products to conventional ones. The results reported here are thus limited to the information available in the original studies. More comparisons of profitability between genetically engineered varieties and conventional ones would of course be useful for the analysis.

Herbicide Resistant Varieties

17. A highly important factor in crop profitability is the ability to control weeds that compete with the crop for soil nutrients, water and sunlight necessary to plant growth. It is estimated that potential crop losses due to weeds amounted to approximately USD 8.4 billion in North America over the 1988-1990 period, making them the most important component of the pest complex (Oerke *et al*., 1994). Under conventional cropping procedures weed control usually requires several applications of different herbicides over the growing season, usually chosen for their specific action, such as pre- or post-emergence and according to dominant weed type. Post emergence weed infestation can be the most costly to farmers because of crop loss and the need to use a variety of herbicide treatments. Biotechnology has been able to genetically modify a number of major agricultural crop varieties to resist the application of wide-spectrum post-emergent herbicides, such as glyphosate based formulas. This permits farmers not only to tend a larger acreage but also to apply herbicide in lieu of tillage to control weeds. As the herbicide is able to control the growth of a wide variety of weeds once the plant has emerged, only one application is likely to be needed compared to three or more under conventional varieties. Though weed management with herbicide resistant varieties does not differ conceptually from conventional weed management, farmers' expectations are considerably greater with the new technology. Though use of the technology appears to be more simple, weed scientists emphasise the "importance of good integrated weed management and careful use of selective herbicides to preserve efficacy of glyphosate, one of the most important herbicides in use today" [15] (Pratley et al, 1999;Peng et al, 1999; Doll, 1999; Owen, 1998). Adoption of a new technology may also be affected by consumer reaction to the product. For producers, which depend on export markets where there is a potential for product segregation and thus added costs to producers, adoption incentives may be dampened. However, the response will depend on the extent of cost reductions generated by their adoption and the final product price in any given year.

18. Genetically engineered varieties are more costly than the conventional varieties, due to a technology fee applied to the seed cost. These fees are based on the need for firms to recoup R&D investments in the development of the patented variety. However, these fees tend to decline over the patent

14. Average yield or cost comparisons between GM varieties and conventional ones should not be attributed uniquely to the former, as numerous other factors are important, such as weather, other inputs or incidence of pest infestation

15. As with all herbicides the issue of weed resistance arises though it is not likely to be more severe for a glyphosate mix than for other herbicides (Owen, 1997). Some resistance to glyphosate has appeared, in Australia and California with respect to ryegrass though the impact is small and has not spread (Doll, 1999) Doll reports that industry scientists have discovered resistance to glyphosate in goosegrass (Eleusine indica), reported to be highly prolific weed and a major annual grass weed in tropical and subtropical regions of the world as well as certain areas of the Midwest US. Many years might be necessary for resistance to appear at problematic levels. The only possible problem is that tied to the use of a unique herbicide over extremely wide areas, which probably is unlikely at this stage.(Hartzler, 1998,1999)

life of the product and are eliminated when the patent expires. Purchase of these varieties also carry specific requirements, fixed under contract, such as, no use or sale of own grown seeds (for up to three years in certain cases). For instance, cotton, maize, soybean and canola seed varieties, commonly known as Roundup Ready (RR) varieties, were specifically developed to be resistant to the active ingredient glyphosate, a herbicide effective on a wide range of weeds.[16] The RR crop varieties are the most widely used genetically engineering herbicide resistant varieties, but others are also on the market, such as Liberty Link (LL) maize, and BXN cotton, which are resistant to different herbicide compositions. The Roundup Ready (RR) soybeans, specifically developed to be used with Roundup herbicide, is the most widely used HR soybean variety in the US today. The following sections summarise the main research findings on pesticide use, yields and profitability for genetically engineered varieties.

Soybeans

Herbicide use

19. Though many of the herbicides that Roundup (glyphosate compositions) displaced are used at lower rates, most of these alternative herbicides are used in combination; thus their rate of active ingredient per acre is likely to be higher.[17] Monsanto surveys report that the amount of active ingredient is lower in fields planted to Roundup-Ready varieties than in conventional ones as farmer' herbicide use is reduced: 70-77 per cent made one application, 22-29 per cent made two and only 1 per cent three. Some studies indicate that users may have used both pre-emergence and post-emergence herbicides(Carpenter and Gianessi, 2000). Analyses of 1997 data carried out in the context of the Agriculture Resource Management Study (ARMS) by the Economic Research Service (ERS) of the United States Department of Agriculture (USDA), does indicate an important reduction in herbicide use for soybeans and some reduction for cotton. See Box 5 for a summary of the ERS study.

Yields

20. Both potential yields and expected costs of weed control programmes are important to determining the range of expected profits and hence the farmer's decision to adopt the technology. Farm survey data and university extension field tests on seed varieties provide valuable information for assessing impacts of HR varieties on yields.

21. A study by the University of Wisconsin agronomy department summarising more than 3000 variety trials from 40 university performance tests in eight northern US states for 1998 finds that Roundup Ready varieties have on average 4 per cent lower yields compared to conventional varieties (Oplinger *et al.*, 1999). However potential yield advantages of conventional varieties may not necessarily be realised in actual field conditions due to poor weed control or injury from pesticides. Furthermore, the development of new genetically engineered varieties with higher yield potentials will likely overcome yield drag as will

16 . Glyphosate is a non-selective, broad-spectrum herbicide that normally cannot be applied to crops without severe plant injury. Glyphosate binds tightly to soil and is metabolised readily by micro-organisms into plant nutrients; therefore it exhibits no residual soil activity (Franz et al, 1997). Glyphosate operates by inhibiting the biosynthesis of the enzyme EPSPS, which is necessary to amino acid synthesis in the plant and required for its photosynthesis activities and is found in the chloroplasts of plant cells. Herbicide resistant varieties are modified to contain an 'extra dose of EPSPS 'in their chloroplasts, so that applications of glyphosate do not interfere with their biosynthesis activities.

17 . Caution must be exercised in interpreting data on herbicide use between HR and conventional varieties in that little information on the distribution of herbicide use is generally available. Comparisons through simple averages may be misleading

the use of conservation tillage practices and narrow row spacing.[18,19] This result is attributed to the use of lower yielding varieties for genetic engineering. Other studies have found that conventional and RR yields are equal (Breitenbach and Hoverstad, 1999).

22. A comparison of USDA estimated national soybean yields and Monsanto grower survey data finds that yields of its RR varieties are 4.5 Bu /acre(.3t/ha) higher, though this comparison did not take into account differences between adopters and non-adopters of the technology (Carpenter and Gianessi, 2000). In weed control research Roundup treated plots appeared to have yields which were 5.3 Bu/acre(.36t/ha.) higher than conventional varieties. However 'some of the conventional treatments in the comparisons may have been tested against weeds they do not control, whereas Roundup is a broad weed spectrum herbicide.[20] At present it appears that there is no yield disadvantage or advantage in using HR Roundup Ready varieties compared to the conventional package.

Profits

23. Results from farm trials of Roundup Ready varieties estimate a USD 6.00 per acre(USD 14.82/ha) economic benefit to farmers due to a reduction in herbicide costs with no change in yields. The change in costs was estimated as the sum of a USD 5.00(USD 12/ha)technology fee plus USD 13.00(USD 32.12/ha) for a Roundup herbicide application less reduced herbicide costs of USD 24.00(USD 59.30/ha (Marra *et al.*, 1998). She notes that other on-farm cost changes, though not accounted for here, could be the restriction on their own seed use, possible out-crossing of the resistance gene to weedy relatives but also a possible reduction in field scouting costs. Similar estimates have been made by consulting firms who calculate the expected increase in profitability at between USD 10.00 per acre(USD 24.71/ha) and USD 6.00(USD 14.83/ha) an acre for HR varieties (Furman and Selz, 1998). Such estimates of expected profitability gains clearly imply that adoption rates of HR soybeans should be quite high.

24. The extent of cost reduction potential and its impact on adoption should depend on how many applications of Roundup are made during the season as well as any additional materials/inputs used. Where farmers used conventional varieties, weed control required a number of pre- and post- emergence applications, thus switching to a single application procedure, though more costly per application, is likely to reduce total costs. Conventional herbicide treatments cost about USD 25.00 per acre(USD 61.77/ha)., while Roundup costs USD 16.50(USD 40.77), including a USD 7.00(USD 17.30) technology fee in 1998. Thus if weed control requires only one treatment, there can be substantial cost reductions. And if there is no change in yields this translates into higher profits. More than one application may however, be necessary due to the non-residual nature of Roundup especially in more southern production areas. Weeds may also tend to shift towards species that are not well controlled by Roundup, thus requiring additional applications of either Roundup or other products (Hartzler, 1998 a, b, 1999).

25. A survey of 800 farmers in Iowa by the National Statistics Service reports that net returns were about equal between the HR and non-HR soybean varieties. It finds that even though input costs were lower with HR varieties so were yields. The bottom line was a net return of USD 145.75 for non-HR

18 . On average, the top 5 RR varieties had 5 per cent lower yields than the top 5 conventional varieties in 200 comparisons. The top five averaging should allay in part the Monsanto criticism of the study which noted that not as many different RR varieties were used compared to conventional ones and that their elite varieties were not included. Monsanto believes that its elite varieties compare favourably with conventional ones. The 1999 university variety trial data have not been compiled and it is uncertain whether this will be done.

19 . Higher yields were however obtained for Illinois, a major soybean producing state.

20 . Carpenter and Gianessi(2000) note that these comparisons make Roundup Ready systems appear to be more effective in these type of studies than they would be in reality, where a grower would tailor his weed programme to use the most appropriate herbicides.(p.66)

varieties and USD 144.50 for HR varieties (Duffy, 1999). A study based on USDA-ARMS survey data finds that the impacts of adopting HR soybeans on variable net profits were not statistically significant (Fernandez-Cornejo and McBride, 2000). For a summary of the main findings of the USDA-ERS study see Box 6.

Box 6. Quantitative analysis of farm-level effects of adopting herbicide resistant varieties

The first econometric estimates of the effects of adopting HR soybeans based on a nation-wide farm-level survey for 1997 find a reduction in total herbicide use and a small, but statistically significant increase in yields. The analysis identifies the main determinants of adoption of HR soybeans as well as the adoption impacts on herbicide use, yields and profits. The herbicide categories are identified according to their active ingredients: glyphosate (post emergent herbicide used with HR varieties), acetamides (pre-emergence herbicides) and other synthetic herbicides. A two-stage procedure in estimation is employed, so that the decision to adopt is first estimated and then economic performance examined. The model used in estimation corrects for self-selection bias and simultaneity in the adoption and herbicide use decision. Failure to correct for self-selection could result in confusing purely adoption decisions with those of economic performance, thus biasing the results.

The study finds that the use of other synthetic herbicides is negatively related to the adoption of HR soybeans with an elasticity of -. 14, while the use of glyphosate is positively related to HR variety adoption with an elasticity of .43, with both parameters significant at the 1 per cent level. This means that for a 10 per cent increase in adoption of HR varieties the use of glyphosate increases by 4.3 per cent. While the use of acetamide herbicides is also negatively related to the adoption of HR varieties, the parameter was not significant. Though the elasticity for glyphosate use is much higher than for the decrease in other herbicide use, given the initial levels of their use this still implies a decrease in total use for 1997.

Yields were also found to be positively related to the adoption of HR varieties, though the parameter values were quite small, with an elasticity of .03. The adoption of HR soybeans does not have a statistically significant effect on profits.

Source : Farm-Level Effects of Adopting Herbicide Tolerant Soybeans in the U.S.A., J. Fernandez-Cornejo, C. Klotz-Ingram and S. Jans. Selected paper presented to the American Agricultural Economics Association meetings, August 1999.

Canola

26. The Canola Production Centre showcase variety tests found that 2 HR varieties outperformed the traditional hybrid varieties in 1999 in certain areas. Analysis of the profitability of HR canola in Canada using actual farm survey data show that yield for HR varieties may be lower than for conventional ones and the cost reductions may not sufficiently compensate farmers for this yield differential (Fulton and Keyowski, 1999). Estimated gross returns are found to be lower than for traditional varieties. Again we have the perplexing result that although returns are apparently not greater than for conventional varieties, their adoption is growing rapidly. The authors suggest that the average results obviously mask large regional differences in terms of yields, previous agronomic practices and known heterogeneity of farmers. Those already using reduced conservation tillage practice would tend more readily to switch to HR varieties as benefits to this group would be greater than those employing conventional tillage techniques. Another important factor in the adoption of herbicide resistant varieties is the relative price of the seed varieties. If conventional seed varieties continue to fall in price, this decreases the relative benefits of HR varieties to farmers. However, given the present distribution of practices, in Canada it is likely that the two types of varieties, all else being equal, will continue to co-exist.

Cotton

27. To obtain similar weed control results, Roundup ready cotton varieties require lower herbicide use than the conventional herbicide treatments, though more than one application of Roundup herbicide is required (Culpepper and York, 1998). An econometric study based on ARMS survey for cotton for 1997 finds that herbicide use, when controlling for other factors, was not significantly affected by the adoption of herbicide resistant cotton varieties. (Klotz-Ingram *et al*., 1999). Based on farm surveys from 2 states in 1998, yield and return data do not indicate a clear-cut advantage to either type of pest control programme (Carpenter and Gianessi, 2000b).

Insect Resistant varieties

Maize

28. Crop losses from insect infestation can be quite substantial. It is estimated that in some regions of the United States, losses may involve up to 10 per cent of the crop. On a world basis between 15 to 20 per cent of crops are lost to pest infestations, though losses are much higher in developing countries and for certain crops. In the United States, ECB(European Corn Borer) is attributed with crops losses of approximately 5 per cent of the total value of US maize production (Hyde *et al*, 2000). Thus pest control strategies are important to both developed and developing country agricultural systems.

29. Insect resistant maize is referred to as Bt maize due to the insertion of a gene that carries the genetic code for the toxin produced by the natural occurring soil bacterium Bacillus Thurigiensis. The toxin is particularly effective against pests of the lepidoptera family to which the European Corn Borer belongs and has been used for well over 25 years in foliar applications in organic and conventional farming for a wide variety of pests. Genetic engineering permits all plant cells to carry the toxin against the target pest, however there is not likely to be substantial reduction in pesticide use because farmers were not widely or intensely spraying for ECB prior to adoption of Bt varieties.[21] Benefits are likely to arise from controlling a pest that was not well controlled before. Adoption of the Bt varieties varies across geographic regions as benefits are closely tied to the probability of different levels of ECB infestation. The decision to adopt is perhaps more complicated than in the case of HR crops because expected profits will depend upon the probability of a severe ECB infestation. Where several types of pests may affect a crop over the growing season it is often necessary to apply other pesticides even though Bt varieties were used[22]. And where weeds are a problem, herbicides must also be applied; though some varieties include both Bt and HR characteristics. The expected costs tied to the probability of other insect infestations or emergence of important weed populations also enter into the farmers' adoption decision.

Yields

30. Studies undertaken by various University extension services confirm the yield advantage for BT maize hybrids through the control of ECB (U. of Illinois, 1998; U. of Minnesota, 1998; Iowa State U.1997). Though 100 per cent control of the ECB is not suggested by the studies, the varieties do reduce the deleterious effects of infestation. It was also found that Bt maize varieties reduce the use of other pesticides normally used to combat the ECB.

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21 . Superficial pesticides were not widely used on maize plants for ECB as the ECB effectively 'bores into the plant' reducing the efficacy of these treatments.

22 Starlink and Yieldgard can protect the crop for both 1st and 2nd generation of ECB over the growing season.

Profitability

31. Marra finds that yield increases from better control of ECB range from 4 to 8 per cent depending on year and location (Marra *et al.*, 1998). The probability of adoption is viewed as the result of weighing the additional seed costs of the Bt variety and the reduction in pesticide costs against expected level of crop infestation and yields. This calculation yields the threshold above which it is economically worthwhile for the farmer to adopt. The economic threshold varies according to average yield and infestation levels as well as to the market price of maize. In a year of heavy infestation (2 or more ECB larvae per stalk) it is estimated that Bt maize yields increase by approximately 11.7 Bu/acre(.73t/ha) over conventional hybrids. However, when infestation is less intense the advantage falls to 4.2 Bu/acre. Estimated economic benefits were found to vary between USD 3.00(USD 7.41/ha) and USD 16.00 per acre(USD 39.53/ha) per acre when maize prices were set at USD 2.20/Bu(USD 86.6/t). Additional costs may be incurred as the ECB as well as cotton bollworms develop resistance, when Bt maize and cotton are grown in the same area (Marra *et al*.1998).

32. Using farm survey data for 1997 and 1998, a comparison of profitability from Bt and conventional maize was undertaken. The additional cost of Bt maize seed was approximately USD 10.00 per acre(USD 24.71/ha) in 1997 and USD 8.00 per acre(USD 19.768/ha) in 1998 compared to conventional hybrids. Assuming that the price of a bushel of maize was USD 2.43(USD 95.66/t) in 1997 and USD 1.95(USD 76.77/t) in 1998 and with knowledge of actual infestation levels, a simple calculation found that the average change in income per acre in 1997 was +USD 18.00per acre(USD 44.48/ha) as ECB infestation levels were high but a –USD 1.81 per acre (-USD 4.55/ha) in 1998 when the infestation was low. In total, farmers gained USD 72 million from Bt maize in 1997 while they lost about USD 26 million in 1998 (Giannessi and Carpenter, 1999). Again averages may be deceptive as the outcomes depend on a farmer's specific level of infestation.[23] Though farmers may decrease their pesticide costs through use of insect resistant varieties, expected benefits depend on infestation levels and associated yield advantages and pesticide use.

Cotton

33. Bt varieties of cotton were developed as alternative pest management strategies to control the principal cotton pests, cotton bollworm and the boll weevil[24]. Bt cotton varieties are, like Bt maize, expected to reduce pesticide use, crop damage and improve farm profits. As in the case of Bt maize, the impacts on profitability depend on the degree of pest infestation in any given year. It is difficult to determine the impacts of Bt cotton on pesticide use due the effects of boll weevil eradication projects in some southern states of the US. However, a Georgia study, following the eradication of boll weevil, compared pesticide use before and after the introduction of Bt cotton, and found that pesticide treatments declined by about 50 per cent. A 1996 study of 300 growers in the Southeast United States found that pesticide applications were 70 per cent lower, yields were 11 per cent higher and profits attributed to Bt cotton adoption were about USD 50 higher per acre (Marra *et al*. 1999). Another survey, based on over 100 sites in Southern and South-eastern United States found that overall the yields on Bt fields were higher, pesticide costs were lower and profits were about USD 40 higher per acre despite increased seed and technology fees (Mullin, 1999). An econometric study based on ARMS data for cotton for 1997 finds that the increase in adoption of Bt cotton led to a significant decrease in insecticide use and significant increases in yields and variable profits. (Fernandez-Cornejo and McBride, 2000).

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23 According to recent studies at various extension offices of land-grant universities, Bt maize (Bt11, Mon810 and CBH351) reduces maize yield losses by about .7 Bu/acre compared to sprayed maize hybrids. However compared to unsprayed hybrids, losses are reduced by 16.6 Bu/acre. This is also a factor that needs to be integrated into the calculations of estimated profitability.

24 . These pests are of the lepidoptera family as is the corn borer. For this reason, where maize and cotton are planted in the same area, refuge requirements are set much higher for maize to avoid pest resistance developing.

Technology Constraints and Profitability Implications

34. Much attention has also been given to the long-term efficacy in the use of Bt crops. Government agencies and scientists in some OECD Member countries recognise that continued exposure to Bt toxins, the unique characteristic of Bt crops, will likely increase the risk of Bt resistant strains of ECB (Alstad and Andow, 1995; Andow, 1999; Benbrook, 1999, Beringer, 1999, Sears and Schaasfma, 1999, EPA and USDA, 1999). Refuge areas are thus recommended by governments, scientists and industry to permit resistant insects to breed with non-resistant insects. Required refuge areas are designated by their probabilities of insect resistance developing, which is a function of both type of Bt variety used and location. Thus, in the northern US states and Canada, the required non- sprayed refuge is about 20 per cent (or 30-40 per cent if sprayed with pesticides), while in southern states, specifically in areas where cotton is grown, it is 50 per cent for a number of varieties.[25] How much refuge optimises producer profits? How does this affect producer decisions to opt for Bt varieties compared to conventional insect resistant varieties?

35. The economic models suggest that, "under normal growing conditions and with a 10-15 year planning horizon, farmers capture most, if not all, of the benefits from Bt technology by planting 20-30 per cent refuge. At lower levels of refuge the economic models are more sensitive to underlying biological and genetic uncertainties. Risk analysis shows that the cost to farmers of planting too much refuge is less than the cost of planting too little refuge"(Sears and Schaafsma, 1999). Increasing refuge from 10 to 20 per cent is expected to decrease the value of Bt technology by less than 1 per cent, while reducing the probability of resistance developing from 37 per cent to less than 1 per cent. On the other hand reducing the refuge from 10 to 5 per cent is expected to increase the probability of resistance developing from 37 to 74 per cent.

36. Recent research at the University of Minnesota suggests using 20-30 per cent of untreated refuge or 40 per cent treated refuge to minimise breeding of resistant strains. However, the increased costs of reducing the risk of resistance with more frequent treatments imply higher costs for producers that may affect their adoption decision. Recently certain producer associations have suggested that required refuge areas be distinguished by their probabilities of insect resistance breeding. Thus in a number of southern states the recommended refuge area is 50 per cent, while in the northern states it is about 20 per cent. The latter estimate also coincides with an analysis undertaken to examine the trade off between risk of resistance and productivity losses under Bt maize, based on a bio-economic model which integrates both economic and biological modelling frameworks (Hurley *et al*, 1999)[26].

25 . These figures are from the US-EPA position paper on integrated pest management. Similar recommendations have been made by the Canadian Plant Health and Production division of the Canadian Food Inspection Agency, though no specification is made for treated refuge area.

26 The US environmental protection agency requires industry to develop and implement pest resistance management plans. The plans use a high toxin level Bt maize and moderate refuge, under the assumption that the resistance gene is recessive and the major resistance genes are sufficiently rare so that non-Bt refuges provide a source for mating.

Recombinant Bovine Growth Hormones-rBST*:*

Dairy

37. The use of recombinant bovine growth hormone (rBGH or rBST) to stimulate milk production is another major contribution of modern biotechnology to agriculture production[27]. Bovine growth hormones are produced naturally in the pituitary gland of cows and as early as the 1930's it was found that if BGH is extracted from one cow and injected into another, it stimulates the latter's milk production. In the late 1970's, research permitted the gene responsible for BGH to be transferred to a bacterium that could be reproduced at reasonable cost (Dobson 1996, Butler, 1999(d)). When rBGH or rBST is administered to lactating cows it increases milk production by as much as 20 per cent with gains in the feed efficiency of between 5 to 15 per cent.[28] In nine long-term rBST research experiments it was found that its use increased milk production over full lactation by 15 per cent on average (standard error of 8 per cent). The developers of rBST reported that it could increase milk production by as much as 20 per cent in well-managed herds

38. Quality of management and nutritional composition affect the size and duration of milk yield response to rBST; thus it is the herds which are best managed that can be expected to increase milk yield the most. Though it has been referred to as a size neutral technology, meaning that equipment and training needed to administer rBST are such that small, medium-size and large dairy herds could profitably use the technology, adoption survey results indicate that it is the largest dairy farms, employing modern management and feed systems which derive the maximum benefits from the technology. Although there is no documented scientific evidence of human health risks from consuming milk from cows treated with rBST, at present there is a moratorium on rBST use in major milk producing countries in the OECD, except the United States.[29]

Potential profitability

39. As with crops, the decision to adopt or not adopt depends on a number factors, above all the expected profitability. To determine if it is worthwhile to adopt the technology a producer may simply estimate the additional revenues realised from rBST less the additional costs. The following hypothetical calculation is adapted from Butler (1999,b) to show that at least theoretically it is a profitable technology. If rBst increases milk per cow by 8lbs(3.62kg) and the average price of milk is USD 12.00 per 100weight (cwt)(USD .26/kg), the additional revenues per cow per day are USD 0.96. This implies expected added revenue over the cow's lactation period (245 days per year) is USD 235.20. How much does rBST cost? A 14 day treatment costs USD 5.50 or USD 0.42 per day per cow. In addition there are extra feed costs, estimated at about USD 0.05 per pound of milk(USD .11/kg) or USD 0.40 per cow per day under the hypothesis of an 8lb(3.63kg) increase in milk produced per day. The extra cost per cow per day in using r BST is about USD 0.82. This implies a net gain of USD 0.14 per cow per day or USD 34.30 per lactation period. If present methods generate profits of USD 1.50 per cwt(USD .033/kg), on cows producing an average of 20,000 lbs. per year, we find that total profits would be USD 300 per lactation under conventional methods, while under rBST she would gain 334.30-300=34.30 or 11.4 per cent. The use of rBST not only increases milk production, but also generates increased profits under our hypothetical, but

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27 . While genetically engineered farm animals have been developed to deliver both higher productivity and improved quality traits to farmers, they are not available commercially, and therefore they are omitted from the discussion.

28 To avoid possible confusion with the use of steroid growth hormones (rBST is a pituitary hormone), the name rBST was adopted though both are used interchangeably.

29 While the human health risks in consuming milk produced by cows treated with rBST has not been evidenced, it is because of negative impacts to animal welfare that the product has generally not been approved outside the United States.

reasonable assumptions. This should imply widespread adoption and continued use. Consumer response to the product may also affect the farmer's decision to adopt. In the early years of rBST there was a heated debate on economic impacts of increased milk production and distribution of benefits of the technology across farmers. Concerns on possible adverse health effects of rBST use were also raised by some consumer groups. And in some states voluntary labelling was undertaken by producers of non rBST milk. Over the years these negative reactions appear to have disappeared in most areas.

Adoption of rBST

40. Yonkers (1992) summarised ex-ante survey data from studies completed during 1984, almost 10 years before the release of rBST, indicating that between 60 and 77 per cent of farmers were likely to adopt the product. Later studies were less optimistic on the adoption levels with 1986-1988 studies indicating that only 42-62 per cent of dairy farmers were likely to adopt. For California, the largest milk producing state, surveys conducted several years prior to rBST being marketed, indicated potential adoption rates of close to 45 per cent (Zepeda, 1990,). However, surveys of dairy farmers in the late 1980's and early 1990's gave evidence of increased concern on the part of farmers about the impact of rBST on animal health and consumer opposition to rBST milk (Lesser *et al*, 1989; Hatch *et al.*, 1991).

41. Surveys undertaken about a year after the product was released showed lower adoption rates than most recent ex-ante surveys. Monsanto reported that only about 10 per cent of US dairy farmers had adopted Posilac, the Monsanto brandname for rBST[30]. Between 30 and 39 per cent of New York farmers and approximately 20 per cent of California farmers were users of rBST, though in California only 8 per cent of the cows were being treated after one year. A survey from the Agricultural Technology and Family Farm Institute (ATFFI) of Wisconsin found that 5.5 per cent of Wisconsin dairy farmers were using rBST, but only about 2 per cent of cows were treated with rBST[31]. Furthermore, the survey found that 54 per cent of dairy farmers said they would never use rBST and 36 per cent said they were unlikely to use rBST in the future. In assessing technology adoption, both farmer and farm characteristics need to be taken into account. It was generally found that rBST adopters compared to non-adopters were younger, more educated and already applying modern management techniques such as Total Mixed Rations and Herd Improvement Programs as well as managing larger herds (Butler, 1999b, 1999c).

42. Five years later, in 1999, an ATFFI survey reported that approximately 15 per cent of Wisconsin dairy farmers were using rBST, more than double the share of adopters in 1995. However, the adoption varied by herd size: 71 per cent of farmers with 200+ head of cattle were using rBST, but only 4 per cent of farmers with a herd size of less than 50 head were doing so. Since only about 48 per cent of the cows in a herd are treated with rBST, it implies that about 15 per cent of dairy cows in Wisconsin are currently treated with rBST. A1998 survey in California found that about 25 per cent of farmers were using rBST on about 30 per cent of their herd, thus less than 10 per cent of all cows are treated with rBST. According to Monsanto, about 30 per cent of dairy cows nationally are using rBST, but since only a maximum of 50 per cent of the herds are treated this implies that about 21 per cent of US dairy farms use rBST (Lesser *et al.* 1999).

43. These limited adoption rates appear to contrast with the expected profits of adopting rBST and also contrast with what was observed for genetically engineered crops, where even under variable or uncertain profitability, adoption of the technology is widespread and rapid. What are some of the possible explanations? One fundamental reason may be that the increased profits from rBST are in practice smaller than expected. A recent empirical study of rBST based on farm survey data found that while rBST did

30 . This 10 per cent of farms accounted for 30 per cent of the US dairy cows, indicating that the technology is not size neutral.

31 The 2 per cent estimate is based on the assumption that only about 40 per cent of each herd are being treated.

increase output per cow treated, the impacts on profits were insignificant[32] (Stefanides and Tauer, 1999). However, the authors also indicate that two-year time span may have been "simply too short for a thorough understanding of the technology." Alternatively, rBST use equilibrium may have been reached such that all adoption rent has been extracted (Stefanides and Tauer, 1999). A similar explanation is suggested by other researchers who note that output increases do not necessarily bring with them increases in profits (Butler, 1999b; Lesser *et al*., 1999). A major problem is that while the number of producers using rBST is fairly stable, many are unsure they are making a profit (Butler, 1999b). Again the time horizon of the analyses may have been too short to evaluate rigorously the economic performance of these technologies. It is also suggested that all rents are being extracted by the industry producing rBST. Studies on welfare effects of genetically engineered crops indicate that all economic agents share in the rents (Moschini *et al*, 1999, Falck-Zapeda *et al*, 1999). Other explanations for low adoption rates, may include concern over consumer reaction and possible effects on herd health, for instance in California it was animal stress which motivated the non adoption.

Summary44. At this stage, strong conclusions on the economic impacts of genetically engineered crops can not be drawn. Though expected profits are often considered a major factor in the adoption of genetically engineered varieties, available studies do not, in general, give consistent evidence of profit increases for adopters compared to non-adopters. Results vary across regions, crops and years. Increased costs of the technology are not uniformly compensated for by yield increases or reductions in pesticide and herbicide use. Nevertheless, the adoption of genetically engineered crops, in particular soybeans, has been very widespread. Herbicide resistant soybeans accounted for over 55 per cent and Bt maize for over 30 per cent of area harvested in the US in 1999. Though yields for HR varieties are not generally higher than for non-HR varieties, there has been a reduction in herbicide use in the case of soybeans. A likely explanation might be that the ease and flexibility that these technologies provide to farmers have stimulated their rapid adoption. For Bt maize, yields tend to be higher for adopters than non-adopters but the effect on profitability is less certain as it is tied to infestation levels of ECB. As in the case of HR soybeans, Bt maize is relatively easy to use and avoids scouting for ECB. There is however, substantial concern about the development of resistant varieties of insects, thus producers are urged to use refuges of non-Bt maize of between 20 per cent and 50 per cent of area planted. In general, Bt cotton adopters have experienced increased profitability, though regional variations may exist. For HR cotton adopters there has been a significant decrease in herbicide use, though profits may not be greater than from conventional systems. Almost all ex-ante estimates of profitability predicted substantial increases in variable profits from the adoption of rBST use in dairy, yet the adoption results have been rather disappointing. Less than 30 per cent of cows in the US are estimated to be treated. Researchers suggest this is tied to the need for a high level of management skills, concern for animal welfare and consumer demand response. Others suggest that rents from adopting may not be going to farmers but to producers of rBST, thus dampening the economic incentive. Econometric studies suggest no effect on profit for rBST. Given the relatively short period of their market availability, it is perhaps too early to provide a rigorous assessment of the benefits and costs of the use of genetically engineered technologies in agriculture. Furthermore, the lack of longer period information may also contribute to the rather variable results reported.

32 The coefficient on rBST in a reduced form model describing profits was negative and insignificant.(Stefanides and Tauer, p.101)

Part 2. Market Issues

45. Markets not only provide for exchange opportunities but also generate information or signals concerning those exchanges to guide future economic decisions. Thus the response of consumers as well as of producers to biotech products must be considered. This section highlights selected demand side issues, which the introduction of modern biotechnology in food production has brought to agricultural markets. As actual consumer response to genetically engineered products in the market is relatively unknown, analysis of the expected market consequences of the introduction of genetically engineered varieties is difficult . However, it is possible to sketch briefly some of the economic issues, which the genetically engineered /non-genetically engineered product configuration may bring to the market. This is done through a brief discussion of labelling options and implications for segregation schemes.

A. Dimensions of Consumer Response

46. How consumer demand might respond to the choice between GE and non-GE foods depends on a set of complex, interrelated factors. At present, this response remains uncertain. Among the many factors that could determine consumer response are: the perceptions of benefits and risks of genetically engineered foods on human health and the environment; consumers' ethical stance towards genetic engineering and their confidence or trust in government regulations in terms of risk assessment and management. The importance of each of these factors in determining consumer response can vary substantially between countries.

47. Surveys of public opinion may provide some indication of public attitudes towards genetically engineered food, but caution is necessary in their use.[33] These surveys are not predictive of actual consumer behaviour in the market but may indicate a tendency in public sentiment. An evaluation of consumer behaviour with respect to GE foods is however, beyond the scope of the present paper. From a number of surveys it appears that differences exist in public perceptions and acceptance of modern biotechnology in agriculture and food production among OECD Member countries. In particular, there are some differences between the United States and the European Union. In the United States, a recent Gallup survey indicates that 48 per cent support the use of biotechnology in food and agriculture production and 41 per cent oppose it (Gallup, 2000). However, 60 per cent of those surveyed by The International Food Information Council thought that biotechnology would benefit them personally[34] (IFIC, 2000). In the European Union however, the 1999 Eurobarometer survey for biotechnology indicates that only about 43 per cent of Europeans surveyed find modern biotechnology in food production useful, about 37 per cent consider it to be morally acceptable and only 31 per cent believe it should be encouraged.[35,36]

48. Other approaches have been used to interpret public opinion on different aspects of modern agricultural biotechnology, such as public consultations, in Australia, France, New Zealand, Switzerland and France and most recently in the United States. The OECD has sponsored two events of this kind

33 . To what extent consumers understand the use of new food technologies, and biotechnology in particular, is difficult to measure, but does not appear very high either in North America or Europe(Gaskell et al, 1999),

34 The latest International Food Council survey of 1000 persons by telephone also found that 69 per cent would be willing to buy GM food products that were protected from insect damage and used less pesticides and over half would purchase GM products engineered to taste better or fresher.(IFIC, 2000)

35 The validity of surveys in representing adequately public opinion depend on the rigor of the methods used, thus not all surveys may be of equal value in assessing public opinion. Those referenced here are considered to have followed standard survey methods to insure that sampling procedures do not affect the results

36 A comparative study of US and EU attitudes towards biotech by the Eurobarometer group has been completed but is not yet officially released

concerning modern biotechnology and food safety: ***OECD Consultation with Non-Governmental Organisations (NGOs) on Biotechnology and Other Aspects of Food Safety***, with over 50 NGOs invited to express their views on biotechnology and agriculture/food and the ***OECD Edinburgh Conference on the Scientific and Health Aspects of GM Foods,*** with over 400 participants invited from a variety of backgrounds, "to identify common ground on whether and how applications of genetic engineering technologies in the food and crops sector" serve the needs of society[37] (OECD,2000). The summaries of these meetings can be found at: http://www.oecd.org/biotech/doc

49. Such public discussions give evidence of the wide variation in the interpretation of available information on genetically engineered foods and the need for open, inclusive and transparent discussion of the issues among all stakeholders.[38] While acknowledging that there are potential benefits for the environment and for human and animal health from the use of modern biotechnology in agriculture and food, a number of concerns are also expressed. *Health* concerns are expressed about the possible long term adverse affects on human health of introducing genetic material from a wide variety of sources into foodstuffs, although no peer reviewed scientific literature gives evidence of adverse human health effects.[39, 40] *Environmental* concerns also exist, particularly with respect to the breeding of resistant pests. Some are also concerned that transgenic plants may be inherently more unpredictable in the expression of their 'new' traits than conventional varieties and thus could generate negative effects on the environment; *Ethical c*oncerns about the sanctity of life or the crossing of species boundaries are often voiced in discussions.[41] Some also wish to expand the ethics discussion to take related socio-economic issues into account.

B. Labelling

Basic issues

50. Differences in individual consumer preferences for genetically engineered products have generated a demand for choice between genetically engineered and non-genetically engineered products.[42] The issue of consumer choice has given rise to a demand for labelling to identify which foods contain and

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37 OECD, C(2000)86/ADD 3, Rapporteurs' Summary, p.7.

38 Participatory decision making processes may help build the public's confidence in the capacity of the regulatory systems to ensure health and environmental safety and thus ease tensions in the ongoing debate. In countries where the public has a high degree of confidence in the regulatory authorities, risk assessments and monitoring procedures are more transparent and participatory with apparently less debate on health and environmental aspects of genetically engineered crops and foods.

39 Among the risks most frequently mentioned are: allergic reactions and increased antibiotic resistance A few specific examples help to clarify the concerns. Allergic reactions, with possible serious consequences were discovered in laboratory tests by Pioneer HiBred when a Brazil nut gene , a known allergen carrier, was inserted into soybeans to increase their oil yield. When discovered further development was terminated. The BT maize variety marketed by Novartis was banned in some member states of the European Union because of its suspected capacity to transmit resistance to ampicillin, a commonly used wide spectrum antibiotic.

40 In arguments for labelling, some have suggested that 'people may be less willing to accept involuntary risk than risks which are voluntarily assumed' (Golan and Kuchler, 1999, p. 1187) Similar comments are voiced by Thompson concerning the ethics of labelling.

41 The opinion of the Committee on the Ethics of Genetic Modification and Food in the United Kingdom, representing some 150 ethicists, philosophers, scientists and religious leaders did not find any specific objection to the use of modern biotechnology in agriculture and food production.). Broadening the scope for labelling to foods produced by genetic engineering, but which have no trace of genetically engineered materials in them, has been raised by some consumer and environmental groups.

42 There may be religious or aesthetic reasons for which individuals might deem it important to know whether genetic engineering has been used. This is an example of individual values, which have been traditionally protected by policies that require informed consent according to Thompson (1996).

which do not contain genetically engineered products[43]. Consumer surveys in many, but not all, OECD countries suggest that consumers wish to have foods produced through modern biotechnology labelled[44].A very brief summary of some of these results is provided in Appendix 2.

51. In a number of OECD countries, certain food manufacturers have established non-GE food lines so as to offer consumers a choice between GE and non-GE foods.[45] This implies that food producers are attempting to respond proactively to expected consumer demands by product differentiation, the costs of which will be born by those consumers with preferences for non-genetically engineered products. The impact on markets depends on whether these food lines remain speciality products limited to a small share of the market or expand to occupy a more significant share of the market, both domestically and internationally.

52. Most foods produced from modern biotechnology are indistinguishable from conventional foods, in terms of appearance or other organoleptic qualities. Goods of this type are classified as credence goods because the consumer can not verify the product attribute either prior to or after consumption[46] (Darby and Karni, 1972; Caswell and Mojduszka, 1996). Credence goods generally entail some type of informational asymmetry. Because of asymmetric information between the producer, who knows if the product contains genetically engineered materials and the consumer who does not, there is a market failure, so market solutions are inefficient and consumer welfare is not maximised. Remedies are often suggested to such information problems(Caswell, 1998b; Caswell and Mojduszka,1996; Hadden, 1986; Shapiro,1983; Beales et al,1981). Labelling is one method suggested to correct for the information asymmetry by providing the buyer with needed information to make her choice. Other approaches include product regulation and minimum product standards. If there are other externalities associated with the product, it is unlikely that labelling will resolve them. In practice, labelling itself raises a number of controversial issues, not all of which can be easily resolved. What are some of these labelling issues?

53. Issues of significant policy relevance are: Whether labelling of genetically engineered foods should be mandatory or voluntary?. Should the label attest to the presence or absence of genetically engineered materials? Should the label refer to content only or also to the production process? What is the tolerance level of GE(non-GE) materials in a non-GE(GE) label? Who is to undertake the testing? Who will monitor and certify testing and labelling procedures so as to ensure that the label is correct and not misleading? Who should pay for the costs of labelling? Other questions arise, such as, how useful is the information conveyed to the consumer by the label? The economic implications of these issues are only highlighted here, although each question merits a more thorough analysis in future work.

43 . Whether foods produced by genetic engineering, but which have no trace of genetically engineered materials in them, should also be labelled, has been raised by some consumer and environmental groups.

44 In the United States, consumers support the present Food and Drug Administration (FDA) guidelines for labelling GM foods only if they are substantially different from traditional ones (IFIC, 2000). Nonetheless, the US government is now to provide guidelines for the labelling of non-GE foods on a voluntary basis.

45 Major supermarket chains, such as Icelandic (UK), Sainsbury (UK), TESCO (UK), Carrefour (FR) CO-OP (Italie), are attempting to have food lines which are essentially GE free. Major processors in Japan have also announced that they are only importing non-GE commodities. And in the United States a number of processors are requesting non-GE commodities for processing, most likely in anticipation of export demand. (Wisner, 1999) For example, certain firms such as Frito-Lay, or Gerber Baby food have announced that they will also use non-GE products in their food lines.

46 . Furthermore it would be impracticable and too costly for consumers themselves to engage in testing of products for their content of repeatedly purchased products, in terms of characteristics, such as, nutritional composition, genetically engineered materials, et al.

Mandatory or Voluntary?

54. If consumers wish to know only if a product contains or does not contain genetically engineered materials, both mandatory and voluntary labelling schemes can remedy the information asymmetry between producers and consumers.[47] In the case of mandatory labelling the government imposes legally binding regulations on sellers to indicate product content and the information problem is resolved for consumers. Under voluntary labelling schemes, the marketplace is relied upon to provide the economic incentive to do so. The policy question is whether labels should be mandatory or voluntary.[48] This involves assessing the objective of the label and the most efficient way to meet the objective. Mandatory labelling is generally advocated for health or safety purposes or where public benefits are at stake rather than purely to differentiate products according to quality attributes. Thus mandatory labelling should have public good qualities. Mandatory labelling may be expensive due to the need to monitor all producers and the administrative costs which this entails. These costs may be financed by lump-sum taxes with possible distortionary effects on the economy or they may be passed along to consumers of the product. For instance where public health or safety is at stake, labelling is often part of a regulatory decision process and costs are not the major factor.

55. When the signalling of product quality or differentiation is needed for marketing purposes then voluntary labelling is suggested.[49] In the discussion on labelling of genetically engineered foods, some suggest that voluntary labels are sufficient to resolve the information problem and are more efficient. For instance, some suggest that those who wish to consume non-genetically engineered products are also those who should accept to pay for the added information(Runge and Jackson, 2000; Shapiro, 1983). There may be cases where there may not be sufficient incentive in the market place to do so credibly . Therefore, under certain market conditions there may be a case for mandatory labelling (Caswell, 1998b, Hussein, 1999). In certain cases, government participation may be required to certify that labels do meet the specified standards or attributes (Beales et al.,1981; Caswell, 1998b; Blandford and Fulponi 1999). In many instances, however, this may be done adequately by third parties, such as the International Standards Organisation (ISO) or by national certifying bodies which certify and enforce quality standards on products.

Positive or Negative labels?

56. Should genetically engineered products be positively or negatively labelled? A positive label, ‘contains genetically engineered ingredients’ under a mandatory system implies by default that those that are not labelled ‘do not contain’ , and vice versa. In either case, labels have the potential to correct the original informational asymmetry and theoretically increase consumer welfare. However given the complexity of modern biotechnology methods and the perception of uncertainties, labels may not carry transparent and significant information (Golan and Kuchler, 2000). How the product is labelled, however, may affect the extent to which the informational asymmetry is removed and consumer choice is

47 . For instance, if the lack of information impedes knowing whether the product contains genetically engineered materials or not, labelling for this removes the problem.. However, such a label may not help the consumer in his evaluation of genetically engineered materials themselves, given information uncertainties.

48 . The policy choices with respect to labelling are much wide and also include labelling interdictions as well as and voluntary labelling whose content is approved by the government (Caswell, 1998a,b) Voluntary labelling with certification by third parties or government standards is also a policy option.

49 . An example of this use is provided in the detailed study on specific types of product differentiation has been undertaken by the Secretariat in the paper, “Designations of Origin and Geographical Indications in OECD members: Economic and Legal Implications”, (COM/AGR/APM/TD/WP (2000) 15/Rev 1.

strengthened.[50] For those who are indifferent between genetically engineered and non- genetically engineered products, a positive or negative label should not matter. For those who wish to avoid genetically engineered foods a simple, positive label, without quantities specified, may not necessarily help consumers make a more informed consumption decision (Kinsey, 1999). This is because about 60 percent of available processed food in most industrialised countries contain genetically engineeered ingredients (Kinsey,1999). Some suggest that it is the negative label, 'contains no genetically engineered ingredients', which might be the more informative, particularly to those not wishing to consume genetically engineered foods, provided the 'no' is well-defined (Runge and Jackson, 2000). Recent analysis of the welfare implications of the a positive or negative labels , finds that welfare distortions are minimised in public labelling systems, where labels are placed on the good with the least elastic demand (Crespi and Marette, 2000).

57. Costs of Labelling Schemes

58. The costs of labelling schemes, including their certification, will be important to overall welfare evaluations. And final results depend on the label carrying meaningful information to the consumer, who can then use it in making a consumption choice. The cost of labelling will likely be a function of the tolerance levels of adventitious GE(non-GE) materials to which the label is to attest, the required testing procedures as well as the cost of monitoring that these procedures are followed all along the food chain. This will entail administrative costs whether done by the public or private sector through third party certification schemes. User fees for certifying the veracity of the label and testing procedures are often used. The question of who pays the cost of labelling will depend on the system adopted, market structure of the industry and the elasticity of consumer demand. In a voluntary system where labels are used to signal quality, these costs can be passed on to consumers. Under mandatory labelling systems or with mandatory public certification, the public purse may pay the costs or these may be allocated between consumers, producers and the government.

Other Externalities

59. Recent analysis however suggests that information asymmetries are only part of the story, as the cultivation and production of genetically engineered varieties may also impose externality costs on producers of non-genetically engineered varieties. These are due to farm level externalities tied to pest resistance development, or crop cross pollination from genetically engineered crops. Producers of non-genetically engineered varieties may then need to absorb additional costs to ensure that their products retain their non-genetically engineered characteristic (Golan and Kuchler, 2000). In this case consumer surplus may decrease with labelling. Simple calculations based on a model evaluating welfare effects from genetically engineered soybeans indicate that when only a moderate proportion of consumers prefer non-genetically engineered products, labelling will not increase consumer welfare and weakens the argument for labelling to increase market efficiency and social welfare. It is also noted that it is the environmental or production externalities that are most often reported by the public as causes of concern for genetically engineered foods. This makes clear that labelling alone will not resolve some of the issues that are closely intertwined with regulatory policy debates concerning the use of modern biotechnology in agriculture. Specific policy tools may be needed to deal with these other externalities.

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50 It is found that mandatory labels are often associated with product warnings, unless the content of the labels is well understood by consumers. (Hadden, 1986) In some instances the label may only transfer the task of analysis of the varied information to the consumer (Golan and Kuchler, 2000). Certain food manufacturers have been against mandatory labelling of such products for this reason.

Government and Private sector responses

60. For the moment labelling remains the standard response to provide consumer choice and to permit markets to function more efficiently. In many OECD countries, specific mandatory labelling regulations for genetically engineered foods have been approved or are in the process of being developed. Among the countries requiring or working on developing and implementing regulations to require labelling of genetically engineered products are Australia, the 15 members of the EU, Hungary, Japan, Korea, Mexico, New Zealand, Norway and Switzerland. The exact rules governing the labelling of these foods differ across countries and in many cases are in the process of being articulated. In the United States, the government is to help establish a voluntary procedure for the labelling of foods containing genetically engineered ingredients [51]. A number of non-member countries also require or are in the process of formulating labelling requirements for foods containing genetically engineered ingredients, both domestically produced and imported, among these are: Egypt, Hong Kong, India, Indonesia, Malaysia and Thailand.

61. Most mandatory labelling procedures put forward by Member countries to distinguish between genetically engineered and non-genetically engineered foods usually attest to the presence of genetically modified materials above a given adventitious or tolerance level[52]. No labels are required where the product does not exceed the specified tolerance level. Where the cost of the label is passed on to consumers, this could reduce the competitive edge in terms of price, which the GE products are expected to provide. But other forms of financing can be considered if labels are considered in the public interest or have public good qualities, such as budgetary financing. Recent research finds that in terms of economic welfare, the labelling strategy should be determined as a function of both the costs of labelling and consumer reluctance towards genetically engineered foods. Where the ratio of consumers highly reluctant to consume genetically engineered foods is greater than those that are indifferent to such foods, positive labels are found to maximise economic welfare in a simple model (Crespi and Marette, 2000). The authors also find that where the ratio of those indifferent towards genetically engineered foods is greater than those who are highly reluctant to its use, the best strategy for mandatory labelling is that of a negative label.

62. Most voluntary labelling schemes that have been put in place by the private sector, in terms of processed foods, specify that the product does not contain genetically engineered ingredients or is not produced from genetically engineered crops. This provides consumers, who wish to avoid genetically engineered foods, with an option. However this also obliges them to bear the costs of the information. Both voluntary labelling schemes, which credibly attest to the 'no genetically engineered ingredients' and mandatory labelling of positive amounts of genetically engineered ingredients can co-exist in the marketplace The difference in approach to labelling of genetically engineered products between the private and the public sector and welfare consequences of each merit further attention.

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51 In the US the label may indicate that the product does or does not contain genetically engineered ingredients, but it must also state that thus far no significant health or environmental effects have been found to be associated with foods produced by biotechnology on the market at present.

52 Where labelling is voluntary, the government may nonetheless place restraints on the content of the labels to avoid misinterpretation of the meaning of the label on the part of consumers as well as to harmonise key pieces of information. An interesting example of US policy is the rBST case. FDA issuing labelling guidelines stated that the labels may not claim milk products are rBST free because that would imply that the milk is different from milk produced with rBST. Vermont however passed a law requiring milk to be labelled as coming from rBST if cows were treated with rBST. Federal courts blocked the law because it failed to include required disclaimer that there was no significant difference between rBST treated cows and those not treated.

Costs of segregation

63. While labels are generally applied at the retail stage or at the final product level, the implications extend to various levels of food processing beginning at the level of the farm and seed producer. Labelling for genetically engineered foods, may imply crop segregation along the food chain. Where the use of a label requires an attestable product segregation trail or certification, an Identity Preservation (IP) system may also be needed. As in all labelling schemes, there are a number of potential externalities to production, consumption and marketing of genetically engineered foods which are important to consider, though these are not dealt with here.

64. Identity Preservation systems are essentially a more stringent form of product segregation. They provides for a number of benefits beyond segregation, such as product traceability. IP systems are already widely used for many crops and livestock products, as they permit the segregation and grading of crops to facilitate sales and trade of products. High value crops such as high oil maize, high protein wheat or speciality products such as organic produce are distributed through systems with some form of identity preservation. In general, IP is undertaken for high value products for which there is a sufficiently high price premium to cover costs. In the US about 8-10 per cent of agricultural production is under IP systems (EC, 2000).

65. The segregation of crops begins at the seed production and distribution levels and continues at the farm level, where both crop production and on-farm storage must be separated. This separation must be maintained throughout the transport, storage and shipping stages until the crop reaches its final destination. Where the crop is exported, separate containers must be used. The definition of tolerance levels, frequency and type of control test procedures are important elements determining the costs of commodity segregation and of IP systems, in addition to any premia arising from market supply and demand conditions. In the case of non-GE crops, tolerance levels refers to the quantity of GE crop which may be tolerated under a “non- GE” label or the quantity above which a positive “GE” label is required. Tolerance arises because of the impossibility, in any practical food processing and handling chain of ensuring absolute purity of products. The concept has been used in the industry for many years[53] (Buckwell *et al*, 1998). Tolerance level controls for the commingling of GE crops with non-GE ones would need to be undertaken at different points in the food chain.[54]

66. Although there is only limited information on cost differentials at present, we may infer costs of GE segregation from similar procedures used for quality traits in soybean and maize. Recent USDA work suggests that crop segregation for High Oil Corn, the added cost of segregation to grain handlers would be about USD 0.22/Bu(USD 8,66/t) or 12 per cent of the 1999/2000 price. For High Oil Soybeans it would be about USD 0.18/Bu(USD 7.09/t) or 4 per cent of the 1999/20000 price (Lin and Harwood, 2000). Other studies also provide cost estimates for IP systems by assuming that these costs are similar to those experienced for high value products and include, costs of testing procedures, transportation and storage differentials and added costs to the processing industry (Buckwell, 1999). The costs range from 5 to 25 Euros/t depending on the grain and the IP system followed. This represents about 6-17 per cent of the farmgate price (EC, 2000). A summary table of these studies is presented in Appendix 3. For instance, soybean protein meal at zero tolerance level can increase the price up to 50 per cent over the GE variety (Buckwell *et al* 1998; USDA(c) 1999). In contrast, a 1 per cent tolerance level increases costs only about USD 26.00/t, or 15 per cent above market prices. Where the product accounts for only a small share in the composition of the final product, the impact on the final price of the product may be relatively small. For

53 . For instance, EU intervention standards for most grains are approximately 3 per cent admixture of impurities.

54 The monitoring required for testing for GM proteins and DNA is costly and often complicated dependent on the stage in the food chain where tests are performed The 2 most widely used methods are the protein based (ELISA) and the DNA based methods using the PCR (Polymerase Chain Reaction). test for presence of specific trait genes.

instance in the case of chocolate, the cost increase from the use of non-GE soybean represents only about 0.5 per cent of the final price. In a study of the costs of IP for the canola industry in Canada, it was found that costs would increase by CAD 33-4/t. However, a breakdown indicates that about 50 per cent of the costs were opportunity costs associated with reduced access to all attractive alternative markets as well as other 'unallocated expenses' (Smith and Phillips, 2000). Without these costs the estimates fell into the CAD 14-28/t range.

67. It is important to underline that the available data do not allow any conclusions on the respective costs of identity preservation versus those of segregation. Thus an economic evaluation or welfare evaluation of either system is not possible at this stage.

68. Who bears the cost for labelling of GE/non-GE products? The costs would generally be shared between the input supplier, farmer, processor, retailer, consumer as well as the government. Who bears the cost of segregating the crops will depend upon the demand/supply situation for GE and non-GE crops as well as the market structure. It is known that the more tightly co-ordinated or vertically integrated a food chain is the more likely it is that farmers with consumers will bear the largest part of the costs. If demand is inelastic it is consumers who bear a large share of the costs, but as these particular products are a small portion of final goods, it is difficult to estimate what part of the cost will be finally borne by consumers. As noted earlier labelling costs may also be financed through lump-sum taxes if it is in the public interest to do so. How these costs will alter the relative demand for GE and non- GE crops is unknown as no empirical estimates of such price elasticities exist as yet.

International dimensions of labelling

69. Many labelling issues are accentuated in an international context where countries apply different labelling procedures, requirements and tolerance levels, for which traded goods must attempt to accommodate each country's regulatory system. A number of multilateral agreements, notably the SPS, TBT, Codex Alimentarius, and the Cartagena Protocol, may potentially come into play in interpreting the trade procedures for genetically engineered agricultural products. The Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) Agreements of the WTO in particular, deal with different aspects of labelling of products in international trade: the SPS deals with matters related to animal, plant and human health and the TBT with all those not covered by the SPS[55]. Both agreements encourage the use of international standards and the SPS explicitly makes reference to the standards of the Codex Alimentarius for food safety[56]. The Codex Alimentarius does not yet have specific guidelines for labelling foods derived from biotechnology. Due to the diversity of opinion on the issue of labelling and given its importance to trade, the Codex Committee on Food Labelling is now developing labelling provisions for foods derived from biotechnology. An Ad hoc Intergovernmental Task Force has also been established by the Codex Alimentarius Commission to develop standards, guidelines or recommendations for such foods. International agreement has not been reached as to specific provisions in either committee. (OECD, SG/ADHOC/FS (2000) 4, p. 6). A preliminary report on this topic is expected in 2001. The *Cartagena Protocol on Biosafety to the Convention on Biological Diversity*, a multilateral environmental agreement to protect biodiversity, may also have implications for trade in genetically engineered crops. According to

55 . "The TBT committee monitors compliance according to the following principles: national regulations must not discriminate unjustifiably between products on account of their origin; measures must have a legitimate aim and achieve it in such a way as to minimise the restrictions on trade; and favourable treatment is given to States which comply with the relevant international standards. Non-compliance may be legitimate, but in such cases there is a transparency obligation and other States must be notified of the proposed regulations so that they can comment upon them. The State in question must establish that the desired aim is legitimate and that the proposed measures are appropriate."(OECD,1999b)

56 . Annex A.3 of the SPS Agreement explicitly refers to the international standards for the Codex Alimentarius in relation to food safety, IPPC for plant health and OIE for animal health.

Article I “the objective of the protocol is to contribute to ensuring an adequate level of protection in the field of safe transfer, handling and use of modified living organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.” Different views on the implementation of the agreement remain particularly with respect to Article 18 which deals with the handling, transport, packaging and identification of living modified organisms. How these different agreements (SPS, TBT, Codex and Cartagena Protocol) will be worked out in the international arena remains uncertain.

C. Market Outlook

70. If modern agricultural biotechnology for food continues to develop as envisaged by the major agribiotech industries through specialised trait commodities, the role of segregation and IP systems will become more important and will most likely bring about significant changes in production, marketing and pricing of major agricultural commodities. For instance, in the United States 70 per cent of speciality crops are now produced under contract. This may also imply different types of relationships between input suppliers, farmers and downstream industries and could have structural effects on agriculture (Coaldrake, 1999).

71. According to the CEOs of Monsanto and Cargill Agricultural Division, within a decade, a quarter of all grain production will be devoted to quality or input traits. Many food industry CEOs also predict that more specialised crops will result in improved profitability for farmers. Within this context it is therefore likely that substantial investments will be made to improve the cost efficiency and reliability of identity preservation systems. Improvement in these systems, whether for IP of non-genetically engineered crops or other special crops, may contribute to improving the performance of the food delivery system by permitting more efficient separation of crops at lower costs.

73. How the demand for genetically engineered and non-genetically engineered products will affect markets is difficult to assess at present as consumer and food industry behaviour as well as government regulations are changing rapidly. The effect of having the same commodity, differentiated by production process or origin, segments the market and creates price differentials. These in turn should generate substitution in animal feeds or between inputs in processed products. The impact will depend on the size of the demand shifts and the relative size of the price elasticities in the different sub-sectors using these products as inputs (Miranowski *et al*, 1999). Market outcomes will reflect relative supply/demand ratios for genetically engineered and non-genetically engineered products and will define any discounts for GE products (Wisner, 1999). If gains from the use of GE technology are large, discounts, if any, applied to GE products will not be important. However, if that is not the case, some reallocation in production between crops will occur. In the early fall of 1999 in certain areas in the United States small premiums for non-genetically engineered crops were being offered: USD 3.9-5.9/t or (4 to 6 per cent of the market price of USD 95/t) for maize and USD 1.8 -12.8(1to 6 per cent of the market price of USD 188/t) for Soybeans(Wisner, 1999). However, these estimates were based on very limited data early in the season, thus no conclusions on premiums for crops should be drawn from this data at present[57].

72. Preliminary model estimates provide a quantitative assessment of the impact of different consumers’ responses to genetically engineered products on world trade patterns for oilseeds and cereals (excluding rice and wheat) with emphasis on developing countries. The results indicate that markets adjust with significant trade diversion occurring and that price differentials are significant, though tempered by arbitrage (Neilsen *et al*., 2000). Using the same general equilibrium modelling framework, other scenario

57 . Wisner reports only the size of the premium per bushel. No estimates were available for the crop year 2000.

analyses indicate that the impacts on world prices and welfare depend mainly on the consumer response in certain large importing countries (Neilsen and Anderson, 2000).

73. On the demand side consumer concerns in numerous OECD countries have generated substantial uncertainty for markets and for the path of future developments in genetically engineered varieties. Little is known as to how these concerns may affect consumption responses and thus the evolution of markets for genetically engineered and non- genetically engineered crops. Many governments have opted to label products containing genetically engineered ingredients to quell some of the uncertainties of consumers and to satisfy their expressed desire for product information. There has been a rapid change in policies regarding labelling of genetically engineered products over the past year in a number of OECD countries. In addition, the food industry appears to be responding proactively to consumer concerns as evidenced by the growing number of non- genetically engineered food lines and by the voluntary labelling schemes being adopted. This behaviour could potentially affect the market evolution for genetically engineered products. Identity preservation procedures to ensure traceability of products are gradually being set up for the main products traded. The exact costs of these are unknown though some similarities may exist with high value crop IP or segregation systems.. How consumers will respond to genetically engineered products once they are labelled is unknown, but their response will certainly have implications for markets, and in particular, for continued adoption of genetically engineered varieties as producers seek to respond to consumer demands.

Part 3. Conclusions

74. The adoption of genetically engineered crops over the past 4 years has been extraordinarily rapid in the United States, Argentina and Canada. Available data and studies are limited, and generally find that in terms of profits, yields and pesticide and herbicide use, genetically engineered crops give varied results across regions, crops and years. Profitability of Bt maize is found linked to the probable severity of pest infestations, which has varied in past years. Cotton producers have however experienced higher yields and increased profits from adopting Bt cotton varieties. For herbicide resistant soybean varieties, notably RR, herbicide use was significantly reduced and small increases in yields were found, but no change in profitability for adopters was found. Similar results are obtained for HR cotton. The adoption results have been less positive for rBST, where less than 30 per cent of cows in the US are treated and economic results do not give any indication of significant increases in profitability.

75. Based on studies for the United States the use of genetically engineered crops tend to imply increased management simplicity and flexibility. Thus adopters may find non-economic advantages to their use. These technologies were expected to be neutral with respect to farm and herd size. In practice, they now appear to have a greater adoption potential for larger farms/herd sizes. Adopters were also found to be younger, better educated and users of advanced farming techniques and management practices. It is too early to properly assess the farmers' response as well as the economic benefits and yield effects of these technologies. Furthermore, there may be risks of developing pest resistance that could affect the economic valuations of these technologies. Only with a longer time series of observations, both from field trials and on farm practices, will one be able to evaluate the overall economic impact of these crops.

76. In many countries, consumer concerns centre on unknown long-term health effects related to GE foods, the effects of GE crops on the environment as well as ethical considerations related to genetic engineering. These consumer concerns or uncertainties have in many countries generated a demand for labelling of products containing or made through genetic modification. This reflects consumers' desire to choose to consume or not consume products, which have been genetically engineered. Their choice may reflect ethical considerations or be based only upon perceived risks to health or to the environment,

irrespective of the availability of scientific evidence. These are, examples of individual values, which have been traditionally protected by policies that require informed consent.

77. The marked differences in consumer preferences across countries have given rise to uncertainty both as regards to domestic and international markets. It is unlikely that the present set of differences in regulatory systems for genetically engineered foods will be easily reconciled or harmonised without a substantial change in policy stances in OECD countries. Labelling, will be able to provide choice to consumers between products that are genetically engineered and those that are not. However, other sources of information will need to be developed for a greater understanding of the use of genetic engineering in food production. How labelling policies, either mandatory or voluntary, evolve will likely have an impact on final demand and thus on markets. Who bears the increased costs associated with the segregation and other procedures necessary for effective labelling schemes and whether positive or negative labelling approaches are used could have important consequences. However, labels may not be able to resolve all issues and possible externalities, generated by the introduction of genetically engineered varieties. Again it is too early to determine the full impact of these factors on consumer response and market evolution and further analysis may well be warranted.

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APPENDIX 1. INDUSTRY STRUCTURE AND AGRICULTURAL BIOTECHNOLOGY: SELECTED ISSUES

Growing firm concentration in the agribiotech industry has recently become a focus of discussion in certain member countries. Though mergers and acquisitions are normal business practice, it is likely that the pace of technological innovation is intensifying the stimulus for structural change in the agribusiness (Kalaizandonakes and Hayenga, 1999). All sectors are however being affected and the agro-food sector is not more affected than others in the economy. Over the past 5 years there has been an increased concentration in the agricultural seed and agro-chemical industry with a surge of mergers, acquisitions (partial or full) as well as growth in vertical co-ordination between upstream and downstream agro-food industries.[58]Some analysts contend that the recent spurt of industry concentration is the result of developments in modern agriculture biotechnology, which feeds upon the development of specialised production processes, requiring tailored inputs that are the output of large research and development operations[59] (Hayenga and Kalaitzandonakes, 1998). These developments provide links to the industrial based economy and a redefinition of the linkages from the farm-gate to end users in what may be called agro-food complexes. It is also likely that industry concentration may be necessary to obtain R&D economies of scale in the race for patents necessary for economic survival. This industry evolution is raising concerns in policy and legal circles. The reasons for this are: possible abuse of market power, effects on product innovation and implications for the evolution of farm structure.

The standard reason for limiting industry concentration is to limit the market inefficiencies from non-competitive behaviour. A number of industries are periodically under scrutiny by the judiciary system in a number of countries. In the case of agribiotech industries, whose profits may be closely tied to the profitability from patented innovations, growing concentration may not just lead to the traditional loss of economic efficiency but also have a negative impact on future innovations (Brennan *et al*, 1999). But these issues are not specific to the agro-food industry. They are part of the general trend to industry consolidation and concentration in all sectors of the economy.

Some of the most important mergers and acquisitions for agricultural biotechnologies have been between the seed, biotechnology and agro-chemical companies. Since 1996 Monsanto has spent almost 8 billion dollars acquiring seed and agro-chemical firms. DuPont, the world's largest chemical company, acquired Pioneer Hi-Bred International the worlds largest seed company for USD 7.7 billion in 1999. Of course similar mergers are occurring in other sectors of the agro-food industry, such as Cargill's acquisition of portion of Continental grains. Tables 1.1 and 1.2 provide some basic information on these merger activities and market shares. More recent reports estimate that the sales of the five largest firms in the pesticide and seed market account for 60 per cent of the pesticide market, 23 per cent of the global seed market and 100 per cent of the GM seed market (Runge and Jackson, 2000). It is interesting to note the linkage from the seed through the processed food sector, a change that could affect the evolution of agricultural marketing and farming arrangements (Busch and Lacy, 1988, Kalaitzandonakes,1999).

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58 . Over the past decade years there has also been a move towards the 'life science complex', involving strategic alliances and mergers of major agricultural and pharmaceutical industries. Now these firms recently appear to be abandoning this concept For instance, though Monsanto merged with Pharmacia-UpJohn, the agricultural portion of Monsanto has been reduced. Other firms such as American Home Products are also reported to be looking to divest their agricultural interests. Novartis and AstraZeneca are also abandoning the concept of Life Sciences. has reduced Monsanto

59 . In particular, the mergers or acquisition of firms specialising germplasm, by seed firms or those with substantial R&D sectors, are seen necessary to assure a sufficient supply of genes for the development of new, tailored varieties.

Table 1.1.Seed and Pesticide Market : 1997

Firms	World Pesticide sales - US$million.	World Seed sales - US$million.	Gmseed varieties % of US market(1998)
Aventis Group(Hoescht/Rhone-Poulenc)o	4,554		88
Novartis	4,199	928	8
Monsanto	3126	1,800	4
Zeneca/Astra(AstraZeneca)s	2674	437	
Dupont	2518	1,800	
Total sales:	30900	23000	
Firm concentration ratio	55,6 %	21,5 %	100 %

Source: Brennan, Pray and Courtmanche. (1999)

Table 1.2. Mergers and Acquisition in Agricultural Chemicals, Biotechnology, Seeds and Food/Feed

	Biotech	Seeds	Agro-chemical	Food/feed
Monsanto	Agracetus(1995) Calgene(1996) Ecogen(13 per cent) Millenium Phamaceuticals	DeKalb(1996) Asgrow(1997) Holden'sFoundation Seeds(1997) Cargill International Seeds, PlantBreeding (1998)	Monsanto	Cargill Joint venture feed and food(Cargill acquires Continental) Montsanto brands such as Nutrasweet
AgrEvo	Plant Genetic Systems(1997) Plant Tec	Nunhems, Vanderhave, PlantGenetic systems, Pioneer Vegetable Genetics(1997) Cargill US seeds(1998)	Hoeschst &Scherring (94) Hoescht &Rhone Poulenc=Aventis	
Dupont	Curagen(1997) Human Genome Science Alliance(1996)	Pioneer(1997 &1998) Hybrinova(1999)	Dupont	Quality Grain(Joint venture with Pioneer) Continental alliance, Protein Technologies Cereal Innovation Nutritious foods
Novartis		Northrup King, S&G seeds Ciba seeds; AstraZeneca-Novartis spin off to Syngenta(1999)	Ciba-Geigy & Sandoz Merck acquires pesticides; AstraZeneca-Novartis spin off to Syngenta(1999	Gerber Foods Archer Midland Daniels joint ventures through Land O' Lakes

Source: Brennan, Pray and Courtmanche;

It is suggested that there is also a close link between R&D behaviour and market dominance, with mergers and acquisitions serving to continue the growth of R&D capacities and innovation production to dominate specific market sectors. This underlines the importance of R&D and the role of patents. The race for patent, is important to the marketing of new products and gaining market share. These new developments often make previous innovations obsolete. As in all races, all competitors are doing the same thing, thus each firm is investing in R&D simultaneously, but who reaps the economic benefit is determined by the first to finish, that is, to gain a patent and market a product (Mansfield, 1986, Brennan *et al.*, 1999). This is a version of Schumpeter's model of creative destruction which has been applied to growth areas for which innovation are key. (Aghion and Hewitt, 1992, Oehmke *et al.*, 1999, Kalaitzandonakes, 1999).

For some, the question is whether the effects of market concentration may affect the innovation process itself. A preliminary study has indicated that recent innovation concentration by a few firms has had an adverse impact on R&D for those not in the top four(Brennan *et al*, 1999). In addition, they find that new firm entry into the market has been reduced and research activity for merged firms 'shows signs of reduced efficiency' (p.20). However, some contend that public R&D may also reduce the economic incentives provided by intellectual property rights for firms. Thus far there is no clear-cut evidence of this (David *et al.*, 1999). In certain OECD countries there is substantial collaborative research effort between private firms and various public sector or publicly funded institutions. [60] Questions also arise as to the appropriate role for public R&D in the agribiotech industry in terms of stimulating further innovations through competition with the private sector as well as in providing innovations in areas where the private sector does not find it profitable to do so. In addition to the increased firm concentration in R&D sectors, there is evidence of growth in the vertical co-ordination of these firms with the downstream sector firms so as to create a co-ordinated food chain, from R&D of specific GM varieties to final products. This may permit them to capture rents all along the food chain. But these are questions that could be applied to a number of sectors of the economy and not just to biotechnology and agriculture. Nonetheless, they represent important issues which are worthwhile to discuss.

60 Much basic and pre-technology research is undertaken by the public sector, such as the GEM the consortium of Federal, State and private seed companies created to identify and introduce new traits into maize germplasm pool that is then used to develop new varieties.

Appendix 2
Table 1 Summary of consumer opinion surveys on the use of labelling for genetically engineered products

Country/	**Survey Author -year- coverage**	**Results**
United States	International Food Information Council; October 2000	52% agree with current FDA labelling procedures. 43% agree with critics who say that any food produced through biotechnology should be labelled even if the safety and nutritional content is not changed;
	March 1997 and February 1999, International Food Council.	Question: Are you more likely agree with the labelling position of the FDA or its critics? (the positions were explained prior to the question)" 58 per cent agree with FDA; 38 per cent with critics.
	1997, Novartis,	"93 per cent of Americans want foods that are genetically altered to be clearly as such including 73 per cent that strongly agree.
United Kingdom	February, 1999, Consumers Association; population representative survey, 1914 adults.	Of those that heard of Genetically modified foods, 94 per cent supported clear labelling of GM foods.
European Union	1997, Eurobarometer, European Opinions on Biotechnology	Question: "It is not worth putting special labels on GM foods : 74 per cent disagree and 18 per cent agreed
Australia	May-June 1999: ANZFA Stakeholders view from public consultations	Question: "Should the criteria for labelling foods produced using gene technology extend to those with the same properites as conventional foods?" 91 per cent stongly favoured mandatory labelling of all food produced with gene technology
New Zealand	May-June 1999: ANZFA Stakeholders view from public consultations	Similar questions to the above: with a large majority favoring mandatory labelling of GM food products.

Appendix 3

Table 1. Summary of estimated costs for Identity Preservation for selected commodities.

	Descripiton	**Tolerance levels**	**Testing and Monitoring**	**Estimated price /cost differentials**
Maize:	High oil content non GM(Europe)	NA	Farm, elevator and miller	+17 per cent of market price
-Non-GM	High oil content(US)	NA	Farm level, Elevator Miller	+5 per cent of farm price(~6$/t) premia due to lower yields of variety +1.2-2$ market price
Soybean-	Hebicide resisant- non GM(US)-for soyameal protein	0 per cent	Farm level through crushing, transportation, and manufacture of soyameal protein	150 per cent of market price
	Hebicide resisant- non GM(Brazil)	.1-1 per cent	Farm costs Lecithin production controls	+27$/t or10 per cent price premia +.8$/t or .1 per cent price premia lecithin
Canola -GM	GM herbicide resistant(Canada)	NA	Farm level Transport/Storage Processing Testing/Monitoring	.73$/t. 6-9$/t 2.-4$/t 3.7$/t total=13-17$/t or 6-8 per cent above market price

Source : Economics of IdentityPreservation for Genetically Modified Crops , 1998
CEAS Consultants: Buckwell,A., *et al*.