Final report of a study

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Economics of Identity Preservation for Genetically Modified Crops

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Contents

A note on terminology and abbreviations

The abbreviation GM is used to refer to Genetic Modification. This phrase is used interchangeably with Genetic Engineering, GE or Gene Technology GT. According to context, the G in GM stands for ‘Genetic’ or ‘Genetically’, the M in GM similarly, can be interpreted in noun form, ‘Modification’ or adjectival form, ‘Modified’. GMO stands for Genetically Modified Organism.

Whilst the definition of what constitutes genetic modification is open to considerable discussion and interpretation, for the purposes of this report it is broadly defined as a collection of techniques of molecular biology including:

- recombinant DNA techniques (gene isolation, purification and engineering techniques);
- enabling technologies (eg, transformation, gene mapping, promoters, regeneration, control of plant functions and some hybridisation systems).

IP refers to Identity Preservation, this is the system of crop or raw material management which preserves the identity of the source or nature of the materials.

S1. Executive Summary and Study Conclusions

1. This study has examined the economic implications and issues relating to Identity Preservation (IP) of agricultural and food products derived from crops containing genetically modified organisms (GMOs). Its primary aim is to provide an objective and independent comparison of IP for traditional reasons, and IP applied to food products containing, or derived from, GMOs. It examines aspects such as what obligations and costs of labelling and any consequential IP may become apparent? How might these costs be shared by the agents in the food chain and how would these costs evolve over time, especially if GM crops become the norm?

   The study was undertaken largely as a desk-based research exercise supported by the collection of data from a variety of sources and interviews including biotechnology companies, food and drink manufacturers, commodity traders, processors/crushers, retailers, seed companies and plant breeders and environmental interest/lobby organisations.

Identity preservation: its rationale and issues

2. IP refers to a system of crop management which preserves the identity of the source or nature of the materials. It is not a new concept since some degree of IP occurs for almost all traded farm produce. Whilst the majority of agricultural products that are internationally traded are subject to limited forms of grading and are traded via a commodity based system, there are a number of more specialised market segments in which more sophisticated IP occurs. These usually reflect additional requirements concerning the content or composition of products and in some cases additional requirements such as specific production processes. In recent years the development of these more specialised market segments, with their need for more sophisticated IP, have increased and reflect two main underlying trends:

   - a drive to add value to raw agricultural products by improving their content and composition, in other words the drive to produce higher and more consistent quality foods;
   - increased concern about consumer health and protection which manifests itself in increased attention to the processes by which food is produced.

3. The prime purpose of this study was to examine Identity Preservation for crops and crop products which have been produced with the benefit of Genetic Modification. The drive for IP in GM crops comes in part from both of these trends and largely reflects the nature

of the technology itself. There are two main categories of Genetic Modification of agricultural crops:

- modifications that focus on *agronomic traits* aimed at improving the profitability of primary agricultural production;
- modifications that focus on *quality traits* which alter the nature of a product.

4. For modifications aimed at improving the profitability of primary agricultural production, the IP issue is complex. As these genetic modifications are essentially cost reducing, there is no intention or desire of the GM provider to change the nature of a crop, only to make it easier and cheaper to grow. Compared with non-GM crops, the GM crop is to all intent and purposes the same. From the supplier perspective this means that there is no economic incentive to initiate IP. The driving force for IP of this category of GM crop therefore comes, not from the supplier but from consumers. Consumer and environmental groups have been active in expressing their views in the print and broadcast media. Their main practical request is for the right to be able to exercise choice on whether to consume food containing ingredients derived from GM crops. To offer this choice it will be necessary to provide appropriate labelling and possible IP of food products. This pressure is based on a mix of ethical, consumer health and safety and environmental grounds. The issues raised by these groups include the following:

- general concern about the application of new technology to food production;
- diminishing public trust in scientists and technical experts whose knowledge and understanding are relied upon to determine whether new technologies are likely to produce unforeseen and unwanted side effects;
- the perception amongst some citizens that the drive to use GM technology in crops comes from a limited number of large companies wielding considerable economic power, which, it is feared, may enable such organisations to influence the regulatory approval process to their commercial advantage;
- a concern that society at large bears most of the risks of long term or diffuse failures of new technology;
- the ethical objection to the transfer of genetic material between species that could not occur naturally. To some, this represents interference with the ‘core’ of life and should not therefore be permitted;
- the perception amongst some citizens that the deliberate, irreversible, release of artificially created genotypes of food crops into the environment should only be made after sufficient consideration of the long-run effects on human health and the environment (ie, these considerations are perceived to be inadequately addressed by current regulatory requirements);

- there are specific concerns that adverse impacts on the environment may arise through possible out-breeding of GM crops, weeds and organisms. There are also concerns that GM technology may bring about further reduction in bio-diversity through losses of beneficial, plants insects and the creatures that depend on them.

In short, there is a lack of confidence amongst some groups in the European population that the competent authorities are adequately dealing with the assessment of long term human health and environmental impacts of GM crops. The remedy sought is recognition of the right of citizens to be able to know what they are eating and how the food they consume was produced so that those who so wish, may avoid GM crops.

5. Genetic modifications for quality traits have the primary aim to develop a new or improved product for which users in the downstream supply chain (notably food manufacturers and processors) and in some cases, final consumers will be prepared to pay price premia for the improved product. In order for suppliers to obtain these price premia it is essential that they maintain the integrity of the product through the supply chain, using IP. Hence, for this category of GM, the drive to develop IP for the GM crop comes from the suppliers' interests.

6. To offer this choice there will have to be a system of labelling of all produce containing or made from GMOs applied through the whole food chain. This raises the issues referred to in paragraph one concerning the obligations and costs of labelling and any consequential IP.

7. The current, relevant regulatory obligations for the suppliers and users of GM technology in the EU stem mainly from the labelling requirements for products containing GMOs (as currently applied to soya and maize). These focus on the measurable and detectable presence of foreign GMOs in food products rather than the production process itself and hence do not require IP to be initiated, except in the context that some products will be required to be labelled as containing foreign GM material[1]. From the perspective of suppliers of GM technology and users through the food chain, these labelling requirements, and consequential IP obligations and costs, determined by the EU regulatory authorities, can be considered to represent the level of (supplier) obligations and costs that European society, as a whole *currently* considers to be reasonable. However, from the perspective of citizens who wish to avoid consuming **all** food containing ingredients derived from GM crops these labelling requirements remain unsatisfactory. The main consequence of this is that, under the current labelling legislation, the only way that such consumers can avoid consuming many GM (soya and

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[1] Labelling is, of course, just one element of IP.

maize) products (ie, those falling outside the requirements of the legislation) is for them to consume foods that are labelled and guaranteed to have been sourced from non-GM crops. This currently requires the initiation of voluntary labelling and possible IP of the non-GM soya and maize ingredients. In other words, a specific market segment would have to be developed for non-GM products akin to animal welfare friendly livestock products and organic produce. In such a case, the onus (and cost) of initiating the necessary IP, monitoring and checking system in which consumers have confidence will relate to the non-GM crop ingredients and this cost will fall on the suppliers of those non-GM crops. The extent to which this may occur will depend upon the costs of the IP required and the willingness of consumers to pay premia for products derived from non-GM crops.

However, if as many groups are demanding, EU labelling regulations were to be changed to require product ingredient labels to make reference to the production process and if this resulted in a significant proportion of European citizens reacting by avoiding products derived from GM crops, then the onus and cost of any IP would probably fall on the suppliers of the *GM* products, rather than the suppliers of the non-GM products (as currently occurs).

The economics of IP: what are the nature of the costs and who bears them?

8. The magnitude of any additional costs of IP will depend on the precise circumstances of the crop and the range of products derived from it, the uses to which they are put, the tolerances and specifications set and the sophistication of the distribution system. For some products, where the crop ingredient is a very small part of the total costs of the final food product, the increment of IP in total costs may be unnoticeable. For others, eg, the use of soya in soya bread, these extra costs may be significant and affect total costs through the supply chain. Also where the IP focuses on the production process, the costs will be affected by the level of controls, monitoring and verification considered necessary to provide adequate levels of consumer confidence. Full IP through the whole food chain requires actions pre-farm, on the farm and at all stages in transport, storage, processing, food manufacture, distribution and retailing.

9. The incremental cost of IP will not be static. It will change as:
   - the volume of the crops requiring IP expands (this could be either GM crops or non-GM crops), there may be economies of size to be achieved, for example in handling and processing;
   - the system operators gain familiarity and ‘learn by doing’, this may lower costs;

- dedicated plant and equipment is used, this may bring cost savings from size economies and from reduced needs for production shut-downs and equipment cleaning;
- the balance of total crop production accounted for by crops containing GMOs changes the incidence of the IP costs. Thus where a GM crop containing an agronomic, cost saving, trait is sufficiently advantageous at the farm level it may supersede the traditional non-GM crop. Once the GM crop accounts for a significant proportion of all traded products, it becomes the norm and will set the baseline for the commodity traded price of the crop at a lower real level than currently occurs. The net effect of this would be to make the growing of the non-GM varieties (with their higher production costs) less attractive to farmers. Such non-GM crops will therefore only be grown if purchasers of the crop are willing to pay a premium price for these varieties relative to the new commodity GM crop that, by then, dominates the marketplace.

10. The incidence of the costs of any IP between the different agents in the supply chain depends on a number of factors.

- First, the price responsiveness of supply and demand for products at each stage of the supply chain. The more unresponsive buyers are to price change (in economic parlance, the more inelastic is demand), the greater the scope for passing on the additional cost in the form of higher prices. Equally, the more responsive buyers are to price change (ie, the more price elastic is demand), the lower the scope for passing on the additional cost in the form of higher prices.
- The second factor is the ultimate responsiveness to price of demand for the final product which itself depends on the substitutability of the product. If there are many substitutes, then responsiveness is high (ie, price elastic) and consequently the scope for passing IP costs on to final consumers is reduced. In such a case, the costs of the IP will reflect back down the supply chain in the form of lower prices.

  For GM quality traits, the aim is to create a new or improved product for which there are no substitutes (or at best inferior alternatives). Such products will generally exhibit less price sensitivity so there is more scope for passing on the additional costs of IP in the form of higher prices.

  For GM agronomic traits the issue is complicated by the nature of the GM. As the trait focuses on the cost of production there is no *direct* value to the end consumer for which the consumer may be willing to pay a price premia. Additionally, the benefit in the form of lower costs of production and thus lower prices through the supply chain is often difficult to demonstrate. As a result, many consumers perceive no benefit from the use of this category of GM technology. If they perceive no benefit, then they will be unwilling to pay more for the product. This reduces the scope for passing on any of the additional costs of IP to the end consumer. IP costs therefore will have to be shared through the supply chain back down to the farm level. In this situation, if the costs of the IP exceed the benefits of the GM crop (that is the farm-level cost savings and yield improvements), then there is no advantage in undertaking the IP or in farmers adopting the new GM technology. For the non-GM crop competing with GM 'equivalents' that contain agronomic, cost saving traits, the position is akin to the case of GM value-adding traits referred to above. An IP system for such crops will only occur if there is sufficient demand amongst consumers for non-GM products. This requires enough consumers who perceive that non-GM products are a superior or 'improved' relative to the modified substitute. Only such people will be willing to pay possible price premia relative to the GM version and hence enable the suppliers of these products to recoup the additional cost of the IP.

- A third factor determining the incidence of the costs of IP is the structure of competition in the food industry. The less competition there is and the more concentrated the structure of a particular processing industry, the more likely that the additional costs of IP will be passed through to the next stage of the supply chain either in the form of lower prices to farmers or higher prices to consumers (or an element of both of these).

- The fourth factor influencing the transmission of additional IP costs between stages in the food chain is agricultural price policies. This is an important consideration in Europe where there is extensive (though declining) government manipulation of prices and quantities produced of some agricultural products. This may have an adverse impact on the transmission of the benefits of, for example, GM agronomic, cost-saving technology by masking the magnitude of the benefits. In turn, consumers will fail to benefit fully from the (price reducing) new technology and some of the dynamics referred to above concerning the relative cost of GM and non GM crops will not become fully apparent.

Empirical evidence on the economics of IP

11. The evidence presented in this report shows that IP of crops in which genetic modification has taken place is already occurring. This applies both to modifications that focus on quality traits and modifications that focus on agronomic, cost saving traits. Examples of IP were examined in three crops, soyabeans, maize and other oilseeds. Four soyabean examples are examined, three for maize and three other oilseed examples were found. These are summarised in Table S.1.

Table S.1: Summary of key IP costs identified

Crop	Characteristic	Country	Main IP elements	Tolerances	Approximate (additional) cost
Soyabeans	Tofu varieties (not GM)	US	Farm level to export market	Not disclosed	Premia not disclosed
Soyabeans	High protein, high oleic, low linoleic, low saturate	US	Farm level Elevator level Processor level Refiner level	Not disclosed	$9-10/tonne $1.8-3.7/tonne $1.8-3.7/tonne $4.4-8.8/tonne Total $17-25.2 (6-9% of farmgate price)
Soyabeans	Non-GM (herbicide resistant)	US	Farm level through crushing and transportation and manufacture of soyameal protein	No detectable GM residue (ie, 0%)	$411/tonne of soyameal protein (a 149% premium over conventional, commodity sourcing)
Soyabeans	Non-GM (herbicide resistant)	Brazil	Non: closed system used. Main costs associated with : Farm cost Testing Production of lecithin Capital costs	0.1%-1%	$27/tonne (10% premium on commodity prices) $0.8/tonne (0.1% premium on lecithin price Overall, 10% premia on farmgate price
Maize	Post harvest chemical	US	Transport, storage, export	Not disclosed	$16/tonne (16% premium)
Maize	High oil content	US	Farm level Elevator level Miller level	Not disclosed	$6/tonne (5% premium on farmgate price) $1.2-2/tonne $10/tonne
Maize	High oil content	Europe	(Farm – Elevator – Miller)	Not disclosed	$20/tonne (17% premium on farmgate price)
Sunflower	High oleic	US	Farm level Elevator level Processor level Refiner level	Not disclosed	$10/tonne $1.8-3.7/tonne $1.8-3.7/tonne $4.4-8.8/tonne Total $18-26/tonne (7-10% premium on farmgate price)
Oilseed rape	High laureate	US	Farm level Other levels	Not disclosed	$10/tonne (excluding yield loss offset which was no disclosed). Costs and premia at other levels not disclosed
Oilseed rape	GM (herbicide resistant)	Canada	Farm level Transport/storage Processor Testing/monitoring	None set	$0.73/tonne $6.-8.8/tonne $2.2-3.67/tonne $3.67/tonne Total $13.2-16.87/tonne (6-8% premium on farmgate price)

12. For the modifications that focus on quality traits, the additional costs of IP presented in the three crop case studies and summarised in Table S.1 fall broadly in the range of 5% and 15% of the farm gate price of the mainstream crop. This is broadly similar to the additional costs, as indicated by price premia, associated with IP of well established, non-

GM, value-added market segments such as waxy maize and white maize. Consequently, it is concluded that it is likely that this level of additional cost associated with the IP is probably reasonably indicative of the long term, real cost of IP for GM crops that focus on quality traits. It should however be recognised that the actual costs of IP vary according to a number of criteria such as the nature of the value-added trait, the value of the trait to the manufacturer or processor and the specifications and tolerances set.

13. For modifications that focus on agronomic traits, it is more difficult to assess whether the current IP costs identified can be considered to be reasonably representative of real, long term additional costs. This reflects the following:

    - the main examples made available to the researchers are relatively recent (ie, apply to a maximum of two seasons) and limited to the IP of *non-GM* (herbicide resistant) soyabeans which would otherwise be sourced through a commodity supply system;
    - there are significant differences in the additional costs of IP identified for non-GM soyabeans. The soyameal protein meal example suggests that the additional IP costs are significant relative to conventional sources of supply (a 149% increase in cost) whereas the other main example (in respect of non-GM soya from Brazil) suggests a much lower level of additional cost;
    - the level of tolerances have an important influence on IP costs. The smaller the tolerances set, the greater the IP cost. This is indicated in the above two examples where the tolerances set for the soyabean meal protein were smaller (ie, more demanding) than the ‘Brazil’ example;
    - the nature of the system set up to ensure IP affects its cost. Where the IP has been initiated in parallel with the existing commodity system and operated by organisations that continue to handle both GM and non-GM product (the soyameal protein example), the IP cost appears to be significantly higher than when a closed and dedicated system of sourcing is used (eg, the Brazil example);
    - there is evidence that the costs of IP (post farmgate) decline once set-up costs and a learning curve of operation has been experienced;
    - the only example identified of positive IP of a GM crop containing an agronomic modification aimed at farmers (in respect of Canadian oilseed rape in 1996 and 1997) suggested that the additional costs of IP were between 6% and 8% of the farm-gate price of oilseed rape. However, this example only applied up to point of first processing (crushing). It was initiated solely to prevent the GM crops entering export markets (ie, outside North America) and no testing requirements or tolerances were imposed.

14. Based on this limited information, and taking into consideration uncertainty about the demand response for products that are subject to IP and labelling, it is the authors view that the additional costs of IP will probably reflect the (lower) levels indicated in the Brazil non-GM herbicide resistant soyabean case example and the Canadian GM oilseed rape example, rather than the (higher) soyameal protein case. This conclusion is based on the judgement that in cases of IP of GM and non-GM crops containing agronomic modifications targeted at farmers, it is most likely that sourcing will be through dedicated and closed systems. Thus specific farms, elevators, and processing plants (maybe regionally grouped) will be dedicated to the GM crop. This is bound both to reduce costs and better guarantee IP than switching between GM and non-GM in the same facility. It is however important to recognise that the costs of IP are directly related to the tolerances set for the product subject to IP. The conclusion above assumes that tolerance levels akin to those in the Brazil soyabean case study example of about 1% would be the norm, rather than the significantly more restrictive ‘no detectable residue’ (0% tolerance level) soyameal protein example. In instances where the stricter tolerance levels are set the cost of the IP will increase accordingly. A summary of the main factors and possible ways in which the ultimate level and nature of any IP associated with agronomic GM traits targeted at farmers may develop is presented in Table S.2.

15. A further unknown element that may offset the cost of IP for GMs aimed at farmers will be the extent to which the cost-reducing technology will result in lower real prices for commodity crops such as soyabeans and maize (the main benefit of the technology). Currently GM soya varieties account for about 35-40% of all soyabeans planted in the US and a significantly lower share of soya output in the other main producing countries. This means that, currently, *non-GM* soya varieties still account for the majority of world production and hence set the baseline for world soyabean and derivative prices, traded through commodity-based systems. In the medium term, if GM soyabean varieties continue to expand their share of overall production as they have in the US over the last 3 years, a position may soon be reached whereby GM soya production accounts for the majority of world production and traded soyabeans and hence GM soya may set the baseline for commodity traded price of soyabeans. Should this occur, it is likely that the benefits of the cost saving will be passed down the supply chain in the form of lower real prices for commodity traded soyabeans. Thus, the baseline price for all soyabeans, including non-GM soya will effectively be set by GM varieties at a lower, real level than currently prevails. The net effect of this would be to reduce the real cost of soyabeans to users and end consumers but make the growing of non-GM soya varieties (with their higher production costs) less attractive to soyabean farmers unless purchasers of beans were willing to pay a premium price for non-GM varieties relative to the new commodity GM-soya (that would probably dominate world trade).

Table S.2: Summary of possible future IP cost developments for agronomic GM traits

GM trait	Driver for IP and consumer reaction	Temporary or permanent	Product subject to IP	Indicator of cost magnitude	Tolerances	Comments
GM trait already widely grown and in use (eg, soya, maize imported as per 1998)	Consumer and regulatory (ie, current labelling regs). Vast majority of consumers largely indifferent	T	GM product	Very small: labelling change only	Not relevant	Supplier simply labels all products as 'produced from GM'. Example, 1997 soya ingredient labelling in the Netherlands
As above	As above but suppliers concerned that there may be a significant segment of consumers who wish to avoid GM products	T (possibly P)	Non GM products	Cost dependent on tolerances. Zero tolerance implies very high cost, larger tolerance reduce costs	Yes	Current soyabean examples exist: see Table S.1
As above	As above except a significant segment of consumers wishing to avoid GM products becomes established	P	Non-GM products	Cost dependent on tolerances but probably lower than example above (learning curve, use of closed systems)	Yes	See Brazil soyabean example in Table S.1
Agronomic GM traits newly introduced (eg, Bt maize and herbicide resistant oilseed rape in Europe)	Consumer calming where it is anticipated there may be a significant segment wishing to avoid GM products	T (possibly P)	GM products	Costs likely to be limited to IP to customers at first point of processing (for a less sensitive market eg, non food use)	Probably not applicable	GM crop subject to IP and channelled to less sensitive market segments: see Canadian oilseed rape example. If segment wishing to avoid GM products remains significant and medium term (eg, 2-3 years) take up of technology will be limited

Some final concluding remarks

16. The introduction of GM technology and probable development of increased use of IP, both for GM crops and non-GM crops, has implications for the nature of relations between different parts of the supply chain. Increased use of IP is essentially a move to greater market segmentation. This, in itself, is an underlying development taking place in most commodity markets, especially those used as case studies in this report. As markets become more segmented there is evidence that a greater proportion of supplies at the farm level are grown under direct contract with processors and food manufacturers. These contracts tend to be private arrangements between the respective parties. This, in turn, means that there may be a decrease in market information and transparency. This may result in lower efficiency of operation in the marketplace, if the reduced level of (price) information leads to poor transmission of market conditions to the farm level. However, there is also a potential benefit from this development, from the farmer perspective, if the increased use of contract growing means an increased level of security for sales, prices received and income.

17. A related impact of increased use of contract growing is the potential for greater vertical integration of the supply chain by single participants (eg, an oilseed crusher, food manufacturer, retailer). This may provide these participants with the opportunity to exercise greater control or influence across different elements of the supply chain and hence have possible adverse implications for competition.

18. In mentioning these two issues affecting the level of competition, it is important to recognise that they are features underlying market development of most agricultural crops and not directly related to the subject of the use of gene technology in agriculture. Consequently, if society considers that the net impact on competition may be negative, the way to address this issue is via changes to competition policy within Europe rather than policy aimed at just one new technology.

19. It is clear from the forgoing that the issues concerning GM for agronomic traits are sensitive and complex. Reduced to its barest essentials, the debate can be summarised as the conflict between the competing rights of citizens to know about the methods used to produce their food and the bio-technology industry’s right to supply their products within the regulatory law. It is our view that IP and labelling can make an important contribution to resolving this conflict. There is a real resource cost associated with IP, but its magnitude and incidence will adjust as GM technology becomes more commonplace. For new GM (agronomic) traits these costs can be viewed as a possible, necessary price for society to pay to ease the introduction of an important new technology with the benefits it offers.

20. Finally, it should be noted that the use and adoption of GM technology to crop production is in its infancy and consequently there is currently limited information concerning costs, benefits and impact of the technology and any demand for additional IP. Many changes are also likely to occur that will impact upon the cost and incidence of IP as applicable to GM crops. Therefore, it can be reasonably argued that there remains a continuing requirement to observe, monitor, record and analyse developments in the market place for IP of GM and non-GM crops.

PART I: The rationale for Identity Preservation of Genetically Modified Crops

1. Origins, objectives and structure of this report

1.1. Origins and objectives of the study

This report, commissioned by the European Food Biotechnology Communication Initiative (FBCI) has been undertaken to explore the economic implications of possible Identity Preservation (IP) and any consequential partitioning of Genetically Modified crops through the food chain for European markets. The study focuses on crops (ie, it does not include bacteria and fungi, or animals) and its primary objective is to provide an objective and independent discussion of the subject of Identity Preservation[2]. The intention is to assist the public debate by identifying the possible economic and commercial implications of IP and consequential segregation of GM crops and their derivatives in the food chain in Europe.

The terms of reference of the study were to do the following:

- identify the issues raised by EU and national level IP requirements and the types of costs and benefits likely to be incurred and their incidence;
- assess and evaluate the economic and commercial costs and benefits, where identified from existing published research and in-house material held by members of the FBCI;
- identify gaps in knowledge and understanding;
- draw conclusions on the acceptability of the costs/benefits identified;
- draw conclusions on the implications and practicalities of adopting IP for different GM crops;
- make recommendations for further, more detailed data collection, analysis and research (if required).

The study was undertaken largely as a desk-based research exercise supported by the collection of data from a variety of sources and interviews including FBCI members, commodity traders, processors/crushers, retailers, seed companies and plant breeders and environmental interest/lobby organisations.

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[2] Although FBCI funded the research, a pre-condition to doing it by Wye College and CEAS Consultants was that 'the report, if put into the public domain, would be the independent and objective findings of Wye College and CEAS Consultants, without editing from the sponsor'.

1.2. Report structure

The report is structured in two parts. Part I provides a conceptual framework to define and explain the rationale for identity preservation of genetically modified crops. Part II assembles empirical information on the current extent and costs of IP.

Part I starts by defining IP and the reasons it is a matter of intense public debate in Europe. It provides an explanation of what IP is and places it in the context of the main types of genetic modification, the nature of the market for the modified crops and the ways in which most agricultural products are traded. It then discusses the rationale for IP of GM crops, highlighting the important differences between the two main categories of GM technology, modifications which alter the nature of a product (value adding traits) and modifications aimed at improving the profitability of primary producers (agronomic, cost saving and yield enhancing traits). The remainder of Part I provides a discussion of the nature of relevant labelling requirements in Europe and their implications before examining the economics of IP – the nature of the costs and who bears them.

Part II uses the framework discussed in the first Part to examine, in a series of crop case studies, the evidence available on the possibilities, problems and impacts of IP as a mechanism for introducing GMOs into the food system. The case studies deal with some of the major crops for which genetic modifications are already commercially available or soon expected to be, namely soyabeans, maize and oilseed rape. The studies consider the adoption of GM technology and the associated costs and benefits of undertaking identity preservation for these crops and their derivatives.

The conclusions of the study are presented in the form of an executive summary and conclusions which is placed at the start of the report.

2. Identity Preservation of Genetically Modified crops: issues and implications

2.1. Identity Preservation: definition and general rationale

The term identity preservation (IP) and its association with genetically modified crops can mean different things to different people. Therefore, it is important, at the outset of this study to define IP and to place this within the context of agricultural products.

IP refers to a system of crop or raw material management which preserves the identity of the source or nature of the materials. In relation to agricultural products this is not a new concept since some degree of IP tends to occur for almost all farm products as they are traded beyond the farm gate. The majority of traded agricultural products are subject to limited forms of grading into different classes and sub-classes for which each class is distinguishable by relatively simple and easy to follow criteria (often based on visual differences). Many products are typically graded or classified at their simplest level according to variety or type. Thus, there are different classes of:

- wheat (eg hard or soft red);
- maize (eg flint, dent, white, yellow);
- barley (eg feed, malting);
- rice (eg round or medium grain japonica, long grain indica, basmati).

These examples are largely based on varietal differences of the respective grains although the grading may also extend to some limited consideration of functional characteristics such as grain size or length, colour, test weight, moisture content, percentage of broken grains and percentage of impurities. Hence, grading can be viewed as a very basic form of IP. Whilst some of these grading criteria can be determined simply by variety and visually, others require the knowledge and expertise of a specialist or the use of specialist testing equipment. These issues are discussed further for some specific crops in Part II and Appendix 1. Once these grades or varieties of the commodity have been isolated, the handling, storage and processing systems have evolved the appropriate mechanisms to preserve the identity through the chain as far as this is required.

The underlying rationale for any form of IP and consequential segregation or grading of agricultural products is to facilitate sales and trade of products from farms to the purchasers at each stage in the food chain, the first stage processors (eg, millers or crushers), food manufacturers, retailers and final consumers. The IP or grading allows the purchaser to choose the appropriate grade or variety for his requirements. It permits impersonal buying and selling ‘on specification’ of crops by enabling buyers to obtain the grade of crop anywhere in the world and be assured or guaranteed as to its characteristics without needing to examine the crop in detail. Thus, a limited, system of widely accepted grade specifications has tended to develop for most agricultural products and been incorporated into standard contracts for the sale of each crop. Distribution systems have developed to facilitate the efficient storage, handling and transportation of large volumes of products to these grades in what is often referred to as the 'commodity-based' trading system.

Although the majority of agricultural products are traded through a commodity based system according to limited grading or very basic IP of the respective crops, there are also numerous examples of more sophisticated IP occurring. It is this form of IP that is the primary subject of this report. Where this occurs the identity preservation steps reflect the additional specifications or requirements requested by purchasers of the product. These tend to reflect two forms of greater sophistication:

- additional requirements concerning the content or composition of products (eg, a given protein content, starch level, oil content);
- additional requirements not related to content or composition (eg, region or country of origin, or method of production, for example organic or welfare friendly products).

The rationale for the IP in both of these forms is the same as under the commodity based system namely, to give customers what they want mainly in terms of quality and consistency. The main difference is that the volumes traded tend to be significantly smaller than those traded via the commodity system. These, more user-specific, forms of IP are not new developments: product content or composition examples include specific grain requirements required by breakfast cereal manufacturers, for bread-making, beer making and starch manufacture. A long established example of IP not related to (measurable) composition is quality wines. The grape and wine industry is long accustomed to IP to ensure specific cepages and vintages are segregated from farm to consumer and marketed appropriately. The classification of IP into these two forms also highlights two important concepts that come into play in considering IP systems, testing and tolerances.

- *testing*. For many crops, IP offers purchasers guarantees and confidence that the product supplied is the one specified. An important part of the IP system is the testing of samples for physical or chemical *content* (eg, of protein content). However, testing is not always possible. For some crops it is not possible to test or measure whether the purchaser's specifications or requirements have been met. This applies to most cases of IP relating to production *process* and, in such cases confidence in the IP (eg, of quality vintage wine, or welfare-friendly animal production systems) relies on the integrity of the supplier and the level of confidence that purchasers have in suppliers and the robustness of the IP system initiated;

- *tolerances*. The issue of tolerance arises because of the impossibility, in any practical food processing and handling chain, of ensuring absolute purity of products. The principle of tolerances in purity standards is long-established throughout the food industry. Thus a specified grain variety may contain up to a threshold level of other grains (eg, maltsters quality requirements for malting barley include a maximum admixture of 2% of other seeds and varieties, whilst EU intervention standards for most grains have a 3% maximum admixture of impurities). A particularly relevant use of such tolerances is that applied to organic crops. Because of the difficulty of eliminating all co-mingling throughout the harvesting, storage, transport, and processing chains, there is a five-percent tolerance of non-organic material allowed in some processed foods derived from and labelled as being made from organic ingredients.

In recent years, there has been significant development of more sophisticated IP systems for agricultural products. There are currently many more systems that aim to trace produce back through the food chain to the point of production (farm level) and to provide purchasers with increasing levels of assurances as to content, composition and method of production. Notable examples include the growth in the development and demand for organic products and quality assured supplies of meat, especially beef and cereals. The motives here have been consumer health concerns, loss of confidence in product content and quality, consumer protection, concern for the environment and ethical concerns for welfare standards in livestock production. The IP principle in these cases is that the consumer is concerned with *process*, how crops are grown, how animals have been fed and looked after. In the beef example, the driving force has been the problem of BSE and its link to contaminated feed.

In addition, an underlying feature of most agricultural product and derivative markets is the drive to add value to products by improving or altering the inherent characteristics of a product for which premia may be charged. This strengthens the competitive position of the added-value product *vis à vis* its substitutable alternatives by differentiating it and potentially reducing the cost of processing (eg, developing a soyabean with a higher oil content). Such technical developments may involve the use of both conventional and GM technology. The main implication of the development of more value-adding is the segmentation of markets and a decreasing importance for non-IP, commodity traded, products. These features of the current market and likely future direction (including market segments based on production processes) are illustrated in Figure 2.1.

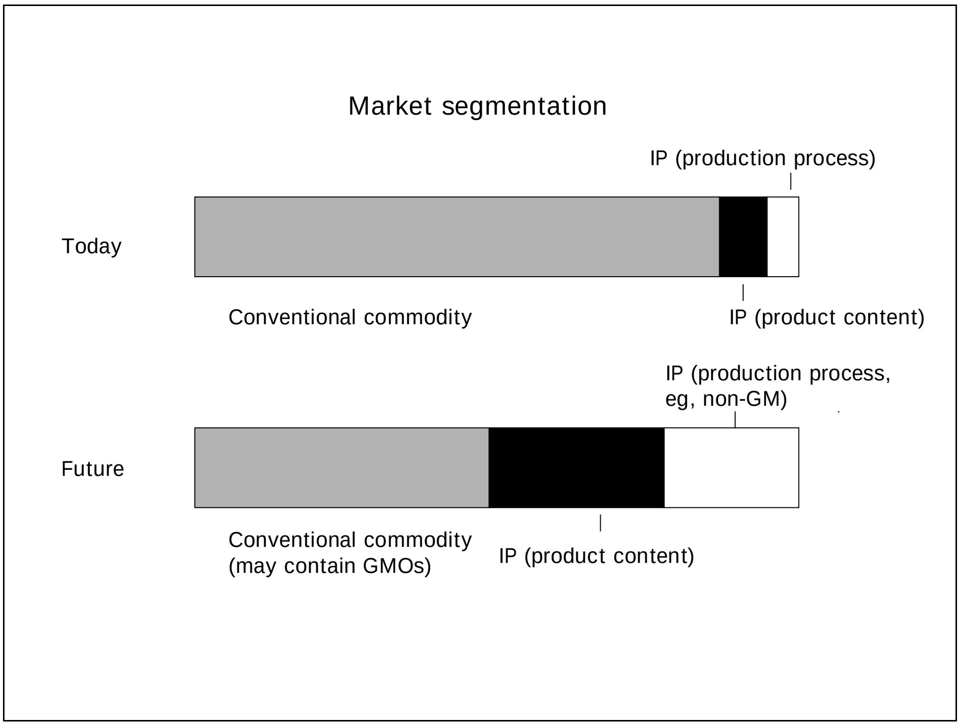

Figure 2.1: Market segmentation

2.2. The rationale for IP for Genetically Modified crops

In examining the economic implications relating to IP of agricultural and food products derived from crops containing genetic modifications, it is important to first consider the underlying reasons and forces driving IP of GM crops in Europe. This in turn requires a little background information about Genetic Modification and citizens' attitudes towards it. The working definition of Genetic Modification summarised at the beginning of the report, emphasised that it is a collection of bio-technological techniques including recombinant DNA techniques and related enabling technologies. Thus GM is a generic term for a family of techniques, and the arguments about it are usually conducted at a very general level. However, it is important to note that each application is absolutely specific: it employs a specific set of techniques on a specific host plant species with a specific modification. The genetic modification usually affects only a tiny part of the host plant DNA, and the new biotechnology is only a minor, but of course highly significant, part of the total effort to produce commercial volumes of GM seed. A great deal of conventional breeding technology is required to ensure that the modified crop not only contains the genetic improvement, but also retains all the other agronomically desirable traits.

Scientists, therefore, debate whether GM techniques are fundamentally different from age-old plant breeding techniques. One school of thought is that, by definition, agriculture is fundamentally a process of modification of domesticated animals and plants to suit the needs of humans. Over time and with better understanding of biology, plant and animal breeders have been able to modify significantly the genotypes of the plants and animals used in agriculture. Many of the processes employed involve interventions, which could not come about naturally[3]. Today's crop plants and animals are very different from their counterparts found in nature, and generally do not interbreed with them. Indeed, some modern hybrids are not viable in the sense that they cannot produce viable seeds. A meaningful definition of genetic modification must therefore involve more than just bringing about a genotype 'which does not occur in nature', for this would include traditional techniques.

Equally, genetic modification cannot be defined purely in term of its effects or the characteristics of the resulting organism. For example, it may be possible to achieve a degree of herbicide resistance in some crop plants either through the conventional crossing of varieties, one of which contains relatively high levels of natural tolerance to a herbicide or genetic modification. Thus for the lay person, the main new element in genetic modification that distinguishes it from conventional plant breeding is the process itself which is used to bring about the modification. If the breeding technique involves the transfer of DNA, as such, then it is generally agreed that genetic modification has taken place. As we shall see later this focus on *process* turns out to be a fundamental point. The concerns of, at least some of, the public is not just the safety of genetically modified crops, but the ethics of the very act of manipulating or modifying the genetic code which defines an organism. This alarm is strongest when the GM involves crosses that would be impossible under natural selection processes and traditional plant breeding methods. Given the uncertainty this engenders about the boundaries and limits for the development of new products, GM technology is widely perceived to be fundamentally different to conventional plant breeding techniques.

The subject of Identity Preservation in GM crops is one in which there is a complex web of interrelating interests and issues which themselves are changing over time. The underlying driving forces for IP comes from the nature of GM technology itself which can be distinguished according to two main categories of intended, immediate beneficiary of the technology. Broadly these two categories can be defined as:

- modifications that focus on quality traits *which alter the nature of a product;*
- modifications that focus on agronomic traits *aimed at improving the profitability of primary agricultural production.*

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[3] Or more accurately, are exceedingly unlikely to come about naturally.

2.2.1. Modifications for quality traits

These comprise genetic modifications which bring about changes in quality traits or make possible industrial and pharmaceutical applications of crops. For example, they may alter the fatty acid composition of vegetable oils or the amino acid composition of proteins. They may stimulate the host plant to produce some vitamin or enzyme. Alternatively they might alter the physical characteristics of the fruits or seeds of the plant, changing its shape or colour. Other modifications can alter the physiological processes in the plant, for example slowing down the process of ripening or decomposition of certain tissues which therefore improves some aspect of quality, extends shelf life and reduces waste. In all such cases the point of the modification is to provide the consumer with a new product or one with improved attributes. The direct beneficiary in these cited cases is plainly the purchaser of the product which may be the final consumer or a food manufacturer. The latter of these two beneficiaries may also derive some cost saving benefits from the technology. These may be achieved by the processors and industrial users through the better matching of raw material characteristics with production process requirements leading to improvements in efficiency. Also, if the modified crop offers reduced variability in the target components of raw materials this will increase efficiency through more productive use of plant and equipment. Both these sources of efficiency gains improve user (processor) profitability and competitiveness and ultimately should also result in benefits at the consumer level (see also further discussion in sub-section 2.4.1).

Clearly the scope for developing new value added crops derived from GM seed will depend on the traits offering real value to users who in turn would then be prepared to pay price premia to farmers to grow crops containing such traits (see sub-section 2.4.1). Once such opportunities are created, it is in the interests of all participants in the supply chain to use IP methods to maintain the integrity of the product throughout the chain. Thus, the underlying driving force for IP in this category of GM product comes from the suppliers'. It is the only way that the desirable properties of the new GM can be identified and paid for. The supplier wants to advertise to the consumer the desirable new features of the GM material and thereby attract purchases.

This category of GM crop is, relatively, uncontroversial. There is agreement between all parties that IP is desirable and practicable. The crops modified for these purposes are more likely to be specialist, minor crops not occupying large areas of crop land. The principal example currently available on the market is the tomato modified to slow the post-picking ripening process and thus to produce tomatoes with less post-harvest spoilage and provide thicker tomato paste. This is regarded as a technical and marketing success. Numerous other GM for quality traits are under development and this 'second wave' of products is expected to gather momentum in the coming years. It is however for GM for agronomic traits over which most discussion has taken place.

2.2.2. Modifications for agronomic traits.

These comprise mainly agronomic resistance and growth traits such as herbicide, insect, nematode and virus resistance and hybrid seeds (which are higher yielding). These traits offer the farmer who plants the modified seeds the opportunity to reduce his labour, machinery, or crop protection chemical inputs. These, in turn, are likely to result in some cost savings. Alternatively, the modification might enable an improved yield of the crop; these would provide their benefit to the adopter by increasing revenue. A third possible avenue for gain to the farmer from the modification is a reduction in risk; this would increase the expected revenue. These are not mutually exclusive, the GM might provide some mix of all of these. The net effect is an enhanced level of expected profit per unit of the crop output.

For these, essentially cost-reducing, modifications, there is no intention or desire of the GM provider to change the nature or composition of a crop, only to make it easier and cheaper to grow. Compared with non-GM crops, the GM crop and its derivatives are, to all intent and purposes, the same as, or substantially equivalent to, the non-GM crop. From the supplier perspective, that is the farmer and those further down the food distribution chain, this substantial equivalence of non-GM and GM product is the basis for arguing that IP of either form of product is unnecessary. Certainly there seems to be no economic incentive to initiate IP from the supplier perspective as there clearly is for value-adding GM crops.

The driving force for IP of GM crops targeted at farmers (agronomic or cost saving traits) therefore comes from consumers, or more correctly, citizens. This arises when people express a desire to have the opportunity to avoid support for, or consumption of, GM crops and their derivatives. This raises several complex issues for IP of GMOs aimed at farmers. The main issue confronting society is the extent to which consumers should have the right and means to exercise choice about whether to consume foods derived from crops containing ‘cost saving’ GM technology. This has implications for IP of crops that do or do not contain modified genetic material and any consequential labelling of food products. European citizens’ concerns about GMOs are a mix of ethical, health and environmental issues. To fully accommodate these concerns by offering choice must mean that the IP and consequential labelling must embrace not only foods which *contain* GM material but also those which have been *made from* GM crops. The focus of concerns is on the process of production as well as the content of food products. The concerns about GM which have been expressed are summarised below[4].

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[4] The reader should note that some of these issues or objections to GM crops apply to all forms of GM crop not just those conveying agronomic, cost saving or yield enhancing traits.

- General concerns about the application of new technology to food production. This results from growing detachment of citizens from agriculture and food production, greater availability of information and time to discuss it.
- Diminishing public trust in scientists and technical experts whose knowledge and understanding have been relied upon to determine whether new technologies are safe and the likelihood that they may produce unforeseen and unwanted side effects. This erosion of trust and faith has developed over many years resulting from some high profile failures of health protection and examples of unforeseen side effects from new technology coming to light mainly associated with pesticide use and intensive methods of rearing livestock. The BSE issue represents a current, example of the perceived failure of the authorities to protect public health which is fresh in the mind of many European consumers.
- The perception amongst some citizens that the drive to use GM technology in crops comes from a limited number of large, often multi-national companies that wield considerable economic power. This power, it is feared, may enable such organisations to exert undue influence on the regulatory approval process to their commercial advantage.
- The concern that society at large bears most of the risks of long term or diffuse failures of the new technology.
- The ethical objection to the transfer of genetic material between species that could not occur naturally. To some, this represents interference with the ‘core’ of life and should not therefore be permitted.
- The perception that the deliberate, irreversible, release of artificially created genotypes of food crops into the environment should only be made after sufficient consideration of the long-run effects on human health and the environment (ie, that current regulatory requirements do not adequately address this concern).
- There are specific concerns that adverse impacts on the environment may arise through possible out-breeding of GM crops, weeds and organisms. There are also concerns that GM technology may bring about further reduction in bio-diversity through losses of beneficial, plants insects and the creatures that depend on them.

In short, there is decreasing confidence amongst some groups in the European population that the competent authorities through the licensing of restricted and general release of GM crops and the labelling of the resulting products, are adequately dealing with these concerns. However, the competent authorities in the EU have already approved the use of and trade in some crops containing and derived from GM crops (notably soyabeans and maize mainly imported from the USA). The argument therefore focuses on citizens’ right to know what they are eating and how the food they consume was produced so that those who so wish, may avoid such (GM) crops. This brings to the fore a large number of questions about IP and possible consequential labelling of GM or non-GM products. How large is the segment of the population that may wish to avoid GM crops? What level of IP and consequential labelling (voluntary or regulatory) to meet these demands might be considered as reasonable by society? What is the cost of any such IP and associated labelling? Who should pay for it?. For the GM crops containing modifications aimed at the food industry and final consumers (quality or value-adding traits), it is clearly in the interests of the supplier to initiate IP and incur any associated, additional costs that may arise. However, for the GM crops containing modifications aimed in the first instance at farmers (agronomic cost saving and yield enhancing traits), there is no supplier incentive to IP or label. The issue then becomes one of assessing the obligation and cost imposed on suppliers via the regulatory authorities.[5] What are the practicalities of doing this? What are the economic consequences? Before attempting answers to these questions, it is important to summarise the existing regulations which affect the labelling of foods derived from GM crops.

2.3. Labelling obligations set by the regulatory authorities

There are several pieces of EU legislation that affect the use and labelling of products containing GMOs. These comprise regulations concerning the restricted (ie, experimental) and general, commercial, release of GMOs into the environment, the marketing of products containing GMOs, the production and marketing of novel foods and the labelling of products containing GMOs. A list of the main pieces of legislation is presented in Appendix 2.

The most important regulatory aspects impinging on the IP issue concerns the labelling requirements for products containing GMOs decided by the European Council in July 1998 (Regulation 1139/98[6]). This regulation has the following key features:

- all labelling is to be founded on **scientific** evaluation criteria that can verify whether a GMO is present or not in a food. Thus tests are to be applied to identify the presence of foreign DNA or protein. If a product contains DNA or protein from a GMO then the product is required to be labelled to indicate that 'it is produced from a GM crop'. This requirement applies to any product containing a GM material and where one or more ingredient contains foreign DNA or protein;
- the above criteria for labelling products containing GMOs will distinguish clearly between products containing GMOs and those not containing GMOs. However, for products that do not contain foreign DNA or protein but which were derived from crops that were cultivated from GM seed (ie, the foreign DNA or protein is effectively removed during processing) there is no requirement to label in any way that differs from other products;
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[5] In its capacity as a competent authority protecting and reflecting underlying consumer interests

[6] This regulation specifically deals with GM soya and maize but is likely to form the base upon which the labelling of all products containing GM will be applied.

- the EU will draw up a so-called negative list of food products which may be derived from GM crops for which there is no GM labelling requirement (ie, the foreign DNA or protein has been removed or destroyed during processing);
- for products that do contain foreign DNA or protein, the positive GM labelling requirement will only apply if the level of foreign DNA or protein detected is in excess of specified tolerance levels. Thus for each such product, the EU Commission will draw up, in consultation with interested parties in the EU, a list of specified tolerances for products. Only if the foreign DNA or protein level is in excess of these tolerance levels will the positive GM labelling requirement be necessary (eg, if the tolerance level is set at 1%, then positive GM labelling will only be required if foreign DNA or protein is found at a level of more than 1% of content).

Two important points to recognise concerning this new EU labelling requirement are, first, that some of the details (relating to products that will require labelling and tolerances) have yet to be finalised. Second, that the labelling requirement defined in the regulation, does not specifically address the concerns of consumers who wish to avoid consuming, and thus supporting, products *derived from* a production process that uses GM technology. Although the list of products that will be required to be labelled and associated tolerances have yet to be established, it is clear that a significant proportion of foods that may have been derived from GM crops but which do not contain any foreign DNA or protein will not be required to be positively labelled as GM. Some observers have suggested that this may apply to the majority of food products. In short, the regulation has come down on the side of the producer interests who have argued that the essential concepts to trigger labelling are whether food *contains* modified DNA, in which case it should be labelled, or whether the product is *substantially equivalent* to non-modified products in which case no label is necessary.

The interpretation here of substantial equivalence is thus based around scientifically demonstrable differences in the chemical, physical or biological make-up of the food. Does it, or does it not, contain (above an agreed threshold) modified DNA? To the extent that the only or main concern about GMOs is their effect on health, there is logic in this approach. If the product is not detectably different from equivalent non-modified products, then it cannot have a health impact. Clearly this provides no comfort to those who are concerned either with the ethics of GM or the impacts on the environment. To the extent that these are the concerns of a significant proportion of the population, then the rationale behind the current European regulation on labelling is inadequate.

From the perspective of suppliers of GM technology and users through the food chain, these labelling requirements and consequential IP obligations (and costs) set by the EU regulatory authorities can be considered to represent the level of (supplier) obligations and costs that European society, as a whole *currently* considers to be reasonable. However, from the perspective of consumers who may wish to avoid consuming products derived from GM crops (ie, they object to the process itself), these labelling requirements remain unsatisfactory and clearly are not perceived to be reasonable by this element of the population. The main consequence of this is that, under the current labelling legislation, the only way that these consumers can avoid consuming many GM products (ie, those falling outside the requirements of regulation 1139/98) is for the food industry to undertake the necessary IP and voluntary labelling. This is likely to occur in two sets of circumstances.

- Some food manufacturers might choose to label all or most of their products derived from crops that may have been grown with GM technology as ‘containing GMs’. This decision could be made if the food manufacturer judged that the GM labelling would not significantly affect levels of consumption of such products relative to non-GM products. That is, if they expected most consumers to be largely indifferent to information contained on the label. In such a case, the cost of the voluntary ‘blanket’ labelling of all products as containing GM even when some may not, would be significantly less than undertaking IP of GM crops throughout the supply chain. The net effect would be whatever loss of sales due to some consumers avoiding the products labelled as containing GMs, plus the small increase in labelling costs, relative to the alternative of initiating IP throughout the supply chain.
- A specific market segment could be developed for non-GM products akin to animal welfare-friendly livestock products and organic produce. In such a case, the onus (and cost) will be on the suppliers of non-GM products to initiate an IP monitoring and checking system of non-GM products in which consumers have confidence. The extent to which this may or may not occur will depend upon the costs of the IP required and the willingness or otherwise of consumers to pay for these costs in products derived from non GM crops. These issues are discussed further below.

2.4. The economics of IP: what are the nature of the costs and who bears them?

2.4.1. The costs

The incremental or additional costs of IP arise because of the additional work involved in handling, storage, transport, processing, cleaning-out of storage bins and processing machinery, and administration of GM crops to ensure that they, and all their derivatives can be identified and kept separate from non-modified equivalent materials. These are real, resource costs. They arise in connection with each of the following stages or functions: pre-farm, farm, transport, further storage, processing, labelling and distribution. The flow chart below (Figure 2.2) summarises these stages and the main categories of costs. Further details are presented in Appendix 3.

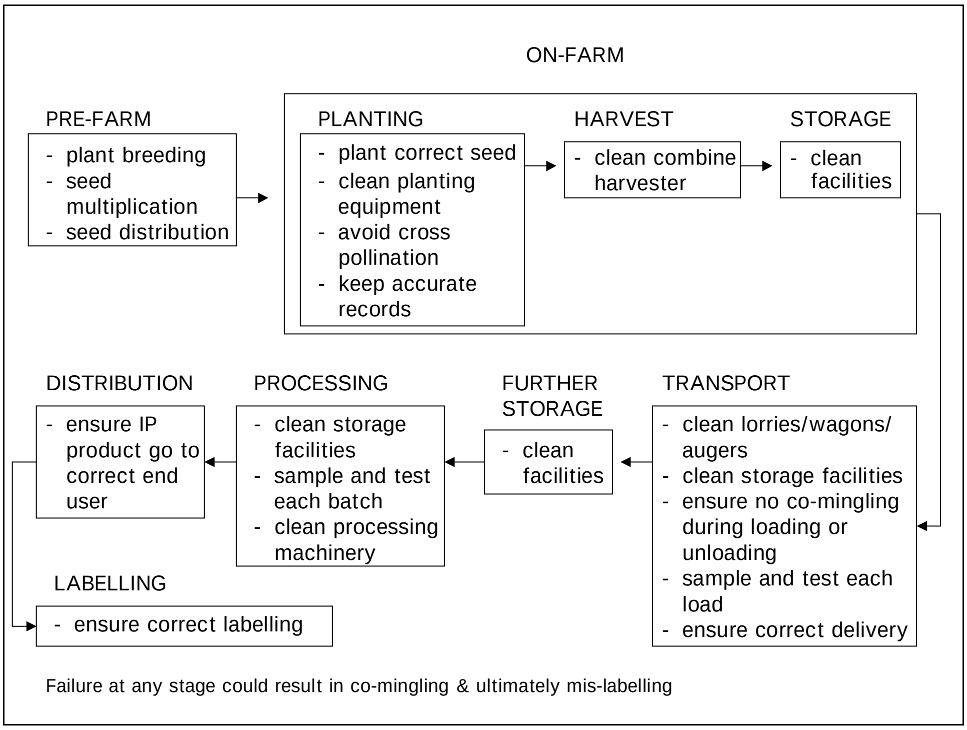

Figure 2.2: Identity preservation

The magnitude of these additional costs of IP will depend on the precise circumstances of the crop and the range of products derived from it, the uses to which they are put, the tolerances and specifications set and the sophistication of the distribution system. Part II provides a series of case studies which offer various degrees of IP and summarises the associated costs.

Two general lessons can be anticipated about these costs of IP. First that there may be a tendency for those who are unconvinced of the need to undertake IP to overstate the magnitude of the costs. Second, IP costs are likely to change as the industry learns how best to organise IP and as the volume of material involved increases.

This has potentially an important effect on the IP procedures required. For example, if a market segment develops for products that were derived from **non**-GM crops, it may not be possible to undertake tests to verify claims that a specific food product contains or is derived from a ‘non-GM crop’. Consequently, such a market segment will only develop if the suppliers to it develop a quality assurance monitoring, control and verification system in which consumers have confidence. For some products, like maize destined for the animal feed market where the extent of processing is small, the additional costs of such IP may cause a significant rise in the feed price per tonne. However, the overall effect on the price of meat is still likely to be limited. For others, like many uses for soya protein or oils in high value processed convenience foods, the soya component is a tiny part of the total product price and the additional cost of IP may have no noticeable impact on the final product price. In addition, it is highly likely that to make IP practicable, some degree of specialisation of growing, storage and processing facilities will develop – either within or between firms and between regions. Thus particular plants (maybe at particular times) may only accept GM or non-modified crops. These issues are examined further in Part II and in Appendix 1 through the presentation of specific examples.

2.4.2. Who bears the cost?

In a market system a cost increase in any part of the food chain is shared between the input supplier, farmer, processor, retailer and consumer. In the case of GM crops, the sharing-out of the costs of IP from one stage to the next depends on the responsiveness of demand and supply to price at each stage[7]. Generally the less responsive is demand, (ie, the less price elastic are consumers), then the more of the cost increase they will absorb in the form of higher price. Equally, the less responsive is supply, (ie, the less price elastic are suppliers), the less their ability to pass on the cost rise to consumers.

The responsiveness of demand to price for raw materials or ingredients at each stage of food processing itself depends on the ultimate responsiveness to price of demand for the final products and on the substitutability of the GM product. If there are many such substitutes then demand is more price responsive. For example, a possible rise in the price of GM soya oil caused by the additional costs of IP may cause food manufacturers simply to switch to non-GM soya oil, or to an alternative oil such as corn oil, sunflower oil or some other substitute. This is a case of a price responsive demand, where the cost of IP can not easily be passed to the processor or consumer. In such cases the costs of IP will be reflected back to the primary producer in lower farm gate prices. In other uses the particular properties of, for example soya oil may be such that other oils are not easily substituted, ie, their price responsiveness is low. In such circumstances the scope for passing on the additional costs of IP are greater and therefore it is likely that these products will carry some of the extra costs of IP in the form of higher prices. A critical price responsiveness in the chain is, of course, at the level of the final consumer. The same principles apply as discussed above. The less price responsive the demand for the end product, the greater the scope for passing on any additional costs of IP in the form of higher prices.

For genetic modifications aimed at consumers - value-adding traits, the GM traits offer scope for food processors to market new and improved products for which consumers may be willing to pay price premia relative to existing products. The supplier attempts to create a situation in which there is limited scope for product substitution and thus more of the

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[7] In technical economics jargon, this responsiveness is measured by the own-price elasticities of supply and demand at each stage of the food chain.

additional costs can be passed on to the consumer. In essence the GM trait is contributing to developing a new and better product, therefore with a better (ie, higher) price. An example is tomato paste made from GM tomatoes whose improved consistency makes better sauces than conventional non-GM derived tomato paste. As the alternative is to consume the now perceived inferior non-GM tomato paste, the demand for the new paste is fairly price inelastic providing scope for the food processor to pass on the additional costs of IP in the form of higher consumer prices[8].

For genetic modifications aimed at farmers – agronomic traits, that offer net revenue improvements (via cost saving, yield enhancement or reductions in risk), the issue is more complex.

First, crops modified with agronomic traits focus on the cost of production and apparently offer no *direct* value to the final consumer. They do not create a new, improved product and therefore there is no incentive for consumers to pay price premia. The only likely instance of willingness to pay a premium in such circumstances is for crops grown *without* using GM technology. This would occur if some consumers perceive non-GM products to be ‘superior’ to GM crops and therefore may be willing to pay premia to cover the costs of IP necessary to provide such products. The scope for passing on the costs of IP for the non-GM product will depend upon how strong the demand for non-GM products is likely to be. The stronger the demand, the more unresponsive to price change and the greater the scope for suppliers to pass on the costs of IP in the form of higher prices. This issue is discussed further in the crop case studies of Part II.

Second, the main benefit of the agronomic, cost saving GM technology is to reduce farm gate prices, and thence, in principle, to reduce prices further down the supply chain. The problem is that this price reduction from a single specific technical change is almost impossible to detect. The agricultural raw material price is a small and decreasing fraction of final consumer food prices. Thus small cost savings at farm level translate into imperceptible price effects at the retail level. Furthermore, such technology-induced price reductions occur in an general economic environment of volatile agricultural prices and general price inflation. The practical result is that the popular wisdom contends that GM for agronomic traits offers no benefits to consumers. This erroneous conclusion is bolstered by the claims of the supply industry – in their desire to calm fears and to avoid the necessity for product labelling - that

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[8] As indicated earlier, there is a clear incentive for suppliers such as farmers, food processors and retailers to initiate IP to retain the identity of the GM value adding trait and hence market a new, distinct product for which consumers may be willing to pay higher prices. In the tomato paste case however, the savings derived at the processing stage also provided scope for reducing the price, as well as offering a new, improved product. Thus, the suppliers did just this, reduced the price relative to the non-GM product (by 10-15%), passing on some of the benefit to consumers but retaining the rest of the benefit as increased margin.

the modified product is substantially equivalent to the non-modified crop. But this has serious effects. Consumers are all too likely, quite rationally, to conclude that if the product is no different, (ie, no better), if it is not noticeably cheaper, and if they perceive some risk, then why should they consume it at all? This is such an important matter it is worth considering in greater detail the nature of the distribution of costs and benefits on a new technology such as Genetic Modification.

The pattern of distribution of the costs and benefits of new technology is complex. Figure 2.3 shows schematically some general principles of this pattern. The horizontal axis represents time, from the start of the first research on the new product, through the launch date, until the product has been fully adopted[9]. The left-side vertical axis represents the aggregate costs or benefits to the various interested parties: the technology supplier, farmers, and consumers. The vertical axis to the right represents the proportion of the final total adopters who have adopted at each period. The precise magnitudes and endurance of the costs and benefits will vary from case to case.

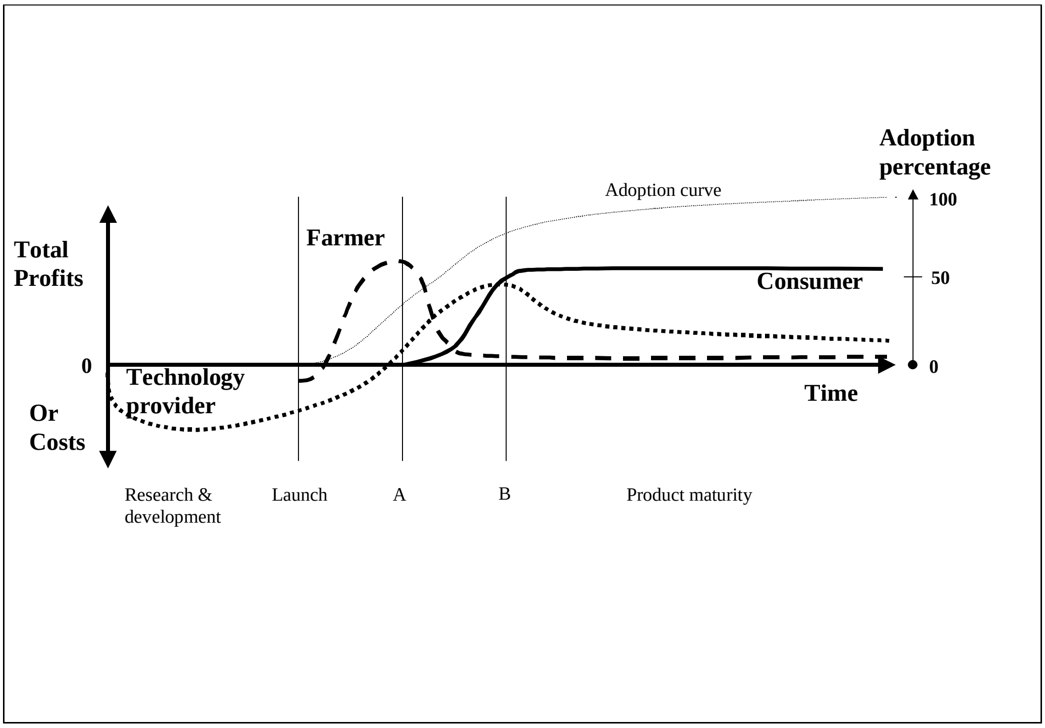

Figure 2.3: The pattern of distribution of costs and benefits of technical change

In Figure 2.3, the thin dotted line shows the classic ‘S-shape’ adoption curve. From the day of launch, there is initially just a small number of farmers –the innovators- who take up the new technology. It may even, initially, cost them more than the new technology returns to do so. They take time to learn how to utilise the new technology, and the early versions are often

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[9] Fully adopted does not necessarily mean 100% of farmers, but 100% of those farmers who, in the fullness of time see it as advantageous to adopt the new technology.

expensive per unit. This is illustrated by the initial farmer 'costs' depicted in Figure 2.3 (the bold dashed line) rather than profits for this period. However, precisely because these farmers are innovative they expect to find ways to make the new technology work and to give them a good return, thus costs soon turn to profits. As the profits materialise, and as the word gets around, more and more farmers adopt it.

As the proportion of farmers using the new technology mounts, it is likely that the supply of the product (eg, herbicide resistant soya or maize) increases. In a normal market this will drive down the price[10]. In the diagram, this happens at time 'A', causing the benefits to the adopters to start to fall. The precise magnitudes of the supply increasing effect and the resulting decline in price depend on the nature of the technical change and the responsiveness (elasticity) of demand for the product, however the direction of these effects is unambiguous.

This fall in price is the main way that new technology in farm production benefits consumers. That it has happened on an enormous scale over the last century or two and especially since World War II is beyond doubt. It shows up as a general decline in real food prices over time. This in turn is reflected in many ways: the proportion of income, on average, which consumers spend on food, or the number of hours or minutes of work, on average, to earn enough to buy, for example, a loaf of bread. These indices have systematically fallen both because of the improvement in productivity of food production and thus in the real costs of food and also, of course, because of improvements in productivity and thus real income in the rest of the economy. This general process of reducing real food prices does not come 'out of the sky' but from the wholesale adoption of new technologies by all producers in the food production chain.

Of course it is very difficult for the consumer to make any link between a specific new technology on the farm (or for that matter in food storage, processing, and distribution) and the price paid in the shops, but the link is real. There is no other explanation for the fall in real food prices. This point is not fully understood, even by the industries supplying GM technology who seem willing to accept the remark that products aimed at farmers provide no benefit to consumers. This simply is not true. It is just very difficult in the modern, long and sophisticated food chain to demonstrate the connection from any individual new technology to the resulting real price fall to consumers[11].

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[10] In the jargon of economics; the new technology shifts the supply curve down – or right – and this results in lower price and a higher equilibrium quantity consumed and produced.

[11] The concept of real prices is difficult enough; with general price inflation the money prices of food never fall. However it is only the relative price of food compared to other goods and services and to income which is important.

There are of course many effects which can mask the link. As time goes on, the raw material component of the price of final food products gets smaller. The food processing industries add more and more value to the raw material. This reduces the impact of, say, a ten-percent reduction in farm gate price, on the price of the processed product at retail level, but it does not eliminate the cost reducing effects of the technical change. Another masking factor is government policy. For various reasons, governments choose to manipulate prices (or quantities produced) of agricultural products. Such interventions in the market can reduce or even prevent the supply shifts and price reductions that are the vital ingredients which transmit the benefits of technical change from producers to consumers[12]. In these cases, the responsibility for any failure of consumers to benefit from the new technology should be laid at the door of the policy makers not the farmers or the suppliers of the new technology[13].

From time ‘A’ (in Figure 2.3), as consumers start to share in the benefits of the new technology (the solid line), there are feed-back effects for the farmers. The erosion of product prices caused by the increased supplies starts to signal a new motive for adopting the technology. Thus instead of the driving force being to increase profits resulting from the cost reduction, it increasingly becomes the need to maintain profits, or even avoid losses by reducing costs. This is what Cochrane (1958) called the technological treadmill. The early adopters make money by adopting the new technology, later adopters are trying to avoid losses. The reason this happens is because the market transfers some of the benefits of the new technology to consumers via the fall in prices. This is illustrated in Figure 2.3 by the eroding benefits to farmers between A and B, and the corresponding rise in benefits to consumers.

By the time ‘B’, the technology has reached ‘maturity’ and has been adopted by all but a few technological ‘laggards’. Thus the full extent of the benefit to consumers is achieved. This may be maintained indefinitely, or it may erode somewhat. The benefits to the technology supplier (shown as the bold dotted line) start as a small negative, ie, costs. These costs grow as the main research and development is done. They then decline as the distribution costs are partly offset by the first sales. Profits to the supplier presumably peak at around the time of mature adoption (time ‘B’) and then decline as competitive products arrive on the market and as the product goes out of patent.

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[12] A classic example is the European dairy sector where the combination of a system of milk production quotas (in which increases in production are penalised) and intervention prices (which artificially maintain milk prices) ensure that very little of the benefit of technical progress in milk production reaches the consumer.

[13] Another masking factor could be imperfections in competition in the food chain. It is the existence of good information, and ease of entry and exit of firm which create the competitive forces which ensure that price reductions at one level are transmitted through to consumers. If market structures are such that these forces do not operate, then, once again, the problem is not the new technology but in this case, the lack of effective competition policy.

In summary, modifications aimed at farmers must indeed offer some benefits to farmers or there is no temptation to adopt them. However, provided the normal forces of the market are free to work, some of the reduced real costs of production brought about by the new seeds must be passed down the line to consumers. The problem is that these benefits will rarely be noticed. This is of course a problem for the technology supplier, who as a result, may lose an opportunity of marketing a profitable product. In a rather superficial way, many would dismiss this problem as unimportant. However if gene technology is perceived as the major new technology which can continue the 20th Century agricultural productivity improvements into the next Century, it is a serious problem for society generally if its progress is hampered by the extreme risk aversion discussed above.

Returning to the likely behaviour of consumers of crop products genetically modified 'for the benefit of the farmer', it might be supposed that there would be a high, even infinite, substitutability between the modified and traditional product. That is, consumers will not consume the modified (new) version at all, especially if the price is no lower, because they perceive the GM and non-GM versions of the product to be inherently the same. This would mean that the consumer would not bear *any* of the associated, additional IP costs. All these costs would then be passed back to the primary producer and processors where they will offset some of the cost saving advantages offered by the GM at the farm level. In such a case if the costs of the IP associated with the GM crop are equal to, or greater than, the cost savings of the technology to farmers then there will be little incentive for farmers to adopt the new technology.

However, it is unlikely that the reaction will be so extreme. The group of consumers who wish to avoid products containing or derived from GM crops will react negatively to the appearance of labels on foods signalling either the 'content of' or 'derivation from' genetically modified ingredients. But this is likely only to describe the behaviour of a segment of the population[14]. Not all consumers read product labels when they purchase goods. Those consumers with less strong views on the subject will probably not be influenced by any positive labelling of GM products and hence be unlikely to alter their purchasing patterns[15].

Some European food manufacturers had already, voluntarily, labelled some products before the introduction of EU Regulation 1139/98 (see sub-section 2.3), eg, biscuits and pizzas as containing genetically modified soya ingredients and consumer reaction (in this case in the Netherlands) is so far reported to have been very small (ie, there has been no significant

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[14] How large or small this segment is likely to be is difficult to assess.

[15] Given that the price of a GM product is not noticeably more expensive than its 'equivalent' non GM product.

change in purchasing patterns by consumers). Whilst such examples cannot be cited as providing definitive evidence of how most European consumers may react to any positive labelling of products derived from GM crops, it suggests that the elasticity of substitution between GM and non-GM products is not necessarily so large. In such cases the additional cost of positive labelling of the GM products is likely, at least in part, to be passed onto and shared with the final consumer. It should be recognised however that the labelling of GM products is only one (small) element of IP. The (Dutch) example discussed above is a case where there is no IP of the modified or non-modified soyabeans or soya derivatives. These ingredients were traded through the normal commodity system offering no segregation or labelling. This cannot therefore be classed as an example of full IP of GM crops in action. The cost of the additional voluntary labelling is likely to be small relative to the costs of full IP of GM crops. This aspect is discussed further in the crop case studies in Part II.

If the GM crop containing an agronomic, cost saving trait is sufficiently advantageous at the farm level it may supersede the traditional non-GM crop. Once the GM crop accounts for a significant proportion of all traded products, it becomes the norm and may set the baseline for the commodity traded price of the crop. Should this occur it is likely that the benefits of the cost saving at the farm level will be passed on down the supply chain in the form of lower real prices for the commodity traded crop and derivatives. In this situation, the baseline price for the crop, both GM and non GM varieties, will effectively be set by GM version at a lower real level than currently prevails. The net effect of this would be to make the growing of the non-GM varieties (with their higher production costs) less attractive to farmers. Unless purchasers of the crop in the processing chain, or if final consumers, were willing to pay a premium price for non-GM varieties relative to the new commodity GM crop, the latter would dominate the marketplace. In these circumstances, the onus for, and costs of, IP would switch from the GM crop to the traditional, non-modified version.

The ability to pass cost increases such as new IP through to the next stage in the food distribution chain is also dependent on the competitive structure of the industry. The less competition there is, and the more concentrated the structure of the particular processing industry, the more likely that the additional costs of IP will be passed back to the previous stage, or forward to the next stage. Because the market power in the food chain is stronger at the food manufacturing and food retailing levels (than either the farm or final consumer levels), this means that they have greater bargaining strength to avoid absorbing cost increases. This in turn means that the cost increases are likely, either to be passed back to the farmer – in the form of lower prices for the raw material, or passed forward to the consumer in the form of higher prices for the finished product. If the costs are passed back to the farmer this will offset some of the benefits of adopting the new (cost saving) technology and may discourage uptake. If the costs are passed onto consumers, it may result in reduced levels of consumption according to the level of responsiveness of consumers to changes in price.

In summary, insisting on IP will create additional costs in the food chain. If initially imposed on GM crops, these costs will be carried by the GM crop and its derivatives, shared through the food chain as discussed above. However, over time, the incidence of the extra costs between agents in the chain and between the modified and non-modified products may change. In addition, extra costs of IP will probably diminish through learning by doing. Once a system is up and running it usually costs less to operate than when it is new and staff have to learn the necessary steps. Also, extra costs of IP are likely to diminish as the volume of the crop subject to IP increases - it will probably be processed and handled by larger and more specialised facilities and the extra costs, for example, of shut down and cleaning of machines will be reduced or may no longer be necessary.

A priori, it is difficult to predict the balance of the various effects of GM technology (especially cost saving modifications aimed at farmers) and any consequential IP and labelling on the costs per tonne of the crop or its derivatives. This balance itself has a complex dynamic pattern, which is illustrated in Figure 2.4. In the very early days of the new crop, ie, in its first season, there may be additional costs all along the chain. The supplier of the technology charges a premium for the new GM seed (to cover the considerable development costs into the product). The farmer may gain little as he is learning to exploit the advantages conferred by the genetic modification. The handling, processing, and general IP costs (per tonne) are high because of the combination of small volume and unfamiliarity. However, once adoption of the new GM crop is well established and economies of size start to be achieved, the price of the GM seed may fall in real terms and farmers' 'costs' turn to gains. The IP handling and processing costs remain and may even rise for a time as larger volumes are involved. However, once the system gets beyond the stage where the majority of potential adopters are using the modified seed, the farm-gate cost of the modified material should fall. As indicated above, if the GM crop has lower growing costs than the non-modified crop, then sooner or later, the market price for all of the crop should fall. If this doesn't happen, then the market is not working and something (for example government policy) must be preventing it working. When this price fall happens, the additional costs for ensuring IP of the GM crop will be offset by the cheaper ex-farm price. The net effect is impossible to predict. It depends on whether the gains from reduced cultivation costs are greater or less than the additional costs of IP.

The general arguments discussed above suggest that initially the GM crop may cost more relative to the non GM version, especially where IP of the GM crop is required. However, the differential will be eroded in time, may vanish and could even become a price advantage in favour of the GM version. The greater the production cost advantage conferred by the modification, the greater the rate of adoption amongst farmers which can be expected and this in turn would mean lower IP costs. This is the case shown in Figure 2.4. The dotted line shows the rise, plateau and then fall of the incremental costs of ensuring Identity Preservation and any consequential labelling (IPL in Figure 2.4). The dashed line shows ex-farm price of the modified crop, which falls after the majority of farmers are using it. The solid line is the vertical sum of the dotted and dashed lines. This may be high in the very early stages, it drops to the extra costs of IP, and then falls as the lower seed costs, at first reduce, and then offset the falling costs of IP. This is of course just one such pattern. The precise pattern depends on the many factors discussed above, not least the consumer reaction.

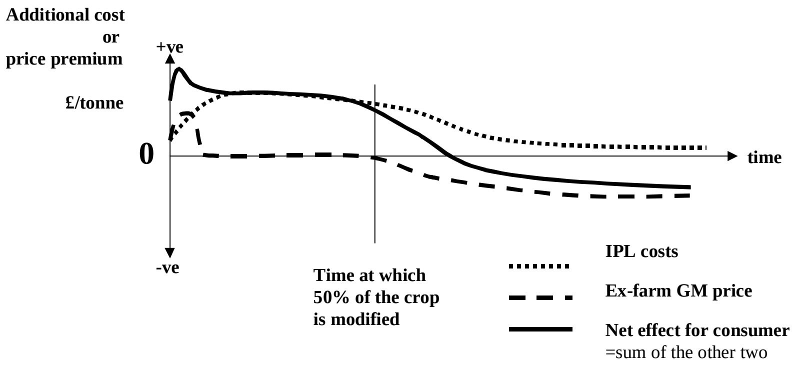

Figure 2.4: The pattern of benefits and costs of Identity Preservation and labelling

Finally, to remove any confusion; it was first argued that GM aimed at 'farmers' would bring benefits to consumers through reduced real prices. Second, it has been noted that if IP and labelling of these modified crops is required, this will impose additional costs which will reduce the advantage to consumers. It has been further argued that these extra IP and labelling costs will diminish over time, and could, if the GM crop is widely adopted, disappear altogether. If this comes about, it will be the non-modified crop for which IP is required and which commands the premium price.

The timing and magnitude of these additional costs or premia per tonne are empirical questions which can only be determined from observation of real world experience. Part II presents the evidence which has been possible to discover up to the time of this report.

Because the technologies are in their infancy and the extent of adoption is still below 50% (even for GM soyabeans in the US), it is not expected that any perceptible consumer benefits will have shown through. These benefits remain a matter of belief and trust.

2.5. IP and GM crops in Europe: a temporary or permanent phenomenon?

The discussion so far has highlighted that the drive for IP of GM from non-GM crops and derivatives is largely determined by a combination of consumer demands, the costs of servicing these demands and the framework set by regulatory authorities. For crops subject to GM traits aimed at consumers (quality or value adding traits), it is in the suppliers' interest to initiate IP and therefore IP of such GM crops is likely to remain a fairly permanent feature of the marketplace. For crops genetically modified to improve the profitability of primary production (the agronomic traits), where there is no supplier interest in initiating IP, the new EU labelling requirements set the current base position. As indicated earlier, whilst some aspects, such as tolerance levels, are yet to be determined, it is likely that a significant number of foods derived from crops that may have been grown from GM seed will not be required to be positively labelled. Hence, for such products there will be no incentive to initiate IP or to change labels to indicate any involvement of genetic engineering. Such labelling will only occur if some food manufacturers choose voluntarily to label all or most of their foods as containing ingredients from crops that may have been grown from GM seed, or derived from such crops (see sub-section 2.3). If this were to occur on a large scale, then soon, most foods would portray a label indicating the GM origin of certain ingredients. If this were to happen, the ubiquity of the label will strongly diminish its force. If most foods have a label mentioning the use, or content, of GM material, then the consumer can be expected to become completely blasé about the issue. At this point it would be reasonable to ask why it is necessary to mention on the label the GM nature of production technology. Consequently under this scenario there would be a strong case for discontinuing the GM labelling and hence such labelling (itself one element of IP) will have been a temporary phenomenon; deemed necessary whilst consumers experienced consumption of GM products and gained confidence in them.

Finally, this leaves a third element in the market, the segment of consumers who positively wish to avoid consuming products containing GMs, including those who object to consuming products derived from the technology even if they do not contain foreign DNA or protein. For these consumers the desire to avoid GM products would lead to IP and consequential voluntary labelling and branding of non-GM crop products. Provided this segment of the population is large enough (and willing to pay for the costs of IP[16]) some suppliers will consider it worthwhile providing non-GM crops. It is reasonable to assume that this form of

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[16] The evidence presented in Part II indicates that currently this is of sufficient size for some suppliers to initiate IP to service this market.

IP and voluntary labelling and branding will be permanent. How large this segment of the market (which would be analogous to the current position of market segments for organic food, or welfare-friendly livestock products) is or may develop is however extremely difficult to predict.

PART II: The mechanics, costs and practicalities of identity preservation

In Part II the issues for IP discussed in Part I are examined in a series of crop case studies. This provides some practical examples of how IP is being applied and its implications and impacts on the specific products and their markets. The intention is to provide some factual basis for the discussion of identity preservation and to give some objective basis for assessing its practicality and economic implications.

These case studies are arranged crop by crop as follows:

- Chapter 3 Soyabeans;
- Chapter 4 Maize;
- Chapter 5 Oilseed rape.

Where relevant (eg, for demonstrating a specific point or issue) additional crop examples have been used.

Each case study is structured as follows:

- The main usage and substitutability of the crop;
- The main features of production and trade;
- The forces for change in the crop sector and the role for genetic modification;
- The examples, issues raised and costs of IP.

The specific examples and case studies of IP include some in respect of GM crops, some in which the IP focuses on the non-GM product, and some where GM is not involved at all. The reader should note that additional information about the main uses and production of each case study crop can be found in Appendix 4.

3. Soyabeans

3.1. The usage of soya

Soya is an extremely versatile crop which provides whole beans, soya protein and soya oil for use in a large range of food products, animal feed and numerous industrial applications. Soyabeans consist of approximately 79% meal, 18% oil and 3% minor by-products. The whole beans are used as seeds, stock feed, sprouts, and baked. The full fat soya flour has many applications in the baking and confection industries. The major soya oil products are refined into oil, soyabean lecithin and glycerol. Refined oil has edible and technical uses. Soyabean lecithin is used as an emulsifying agent in the baking and confectionery industry, and in numerous technical uses as an agent for anti-foaming, anti spattering, dispersing, stabilising and wetting in many industries. The major soyabean protein products are soy flour concentrates, isolates and soyabean meal. The flour is used in many technical non-food industries as well as in many food and drink products. The meals are a major protein source in animal feed rations for all classes of farmed and pet animals. As soyabean meal is a rich source of protein and has an excellent amino acid balance compared to other vegetable proteins, it tends to be the preferred vegetable protein supplement in animal feeds (notably pigs and poultry) and accounts for over 60% of total protein meal used globally. Use in animal feeds is thus the main use of soyabeans relative to food and industrial uses. Appendix 4 summarises information on the main applications.

As soya is an oilseed, it faces competition from other (oilseed) sources of oil and meal in all markets where it is utilised.

a) *Oil*

Potential uses of vegetable oils depend largely on the characteristics of the constituent fatty acids, hence there is not complete substitutability between oils. There are also differences in taste and shelf life. However, broadly speaking, products can be reformulated to use different types of oil and hence there are few guaranteed or vegetable oil-specific markets (ie, the level of substitutability is considerable). Thus, the use of, and demand for, soya oil is fairly price elastic (ie, it is very responsive to changes in price: see sub-section 2.4). The four principal vegetable oils globally are Soya oil (27%), Palm oil (23%) Rapeseed oil (15% and Sunflower oil (12%). Despite the fact that soyabeans account for about half of the world oilseed production, they account for a relatively modest proportion of world oil consumption. This is because soyabeans have a relatively low oil content compared to other oilseeds, especially when compared to palm oil.

As indicated above, soya oil is mainly used for baking, frying, cooking, in salad dressings and in margarine. Its main competitors in European markets are Rapeseed oil, Sunflower seed, Olive oil and Groundnut oil.

b) Meals

Oil and meals are widely used as an animal feed ingredient mainly as a source of protein. Consequently, most protein sources are considered to be largely interchangeable from the point of view of feed manufacturers and hence, price tends to be the key determinant influencing which meals are used (ie, demand is elastic: see sub-section 2.4). Nevertheless, different oilmeals have different nutritional values, and some (notably soya) are considered to be a necessary ingredient in certain compound feeds (ie, demand is less elastic or price responsive than direct substitute ingredients), whilst others tend to be used only when price considerations allow. The major sources of protein meals globally (1996/97) are: Soya beans (62%), Oilseed rape (12%) Cottonseed (8%) and Sunflower seed (7%).

Animal by-products such as fish, meat and bone meals are potential substitutes for oilmeals, as are those derived from cereals such as maize gluten feed. Soya meal, with its relatively high protein content of 44-50%, is however considered to be the most important oilmeal.

3.2. Soyabean production and trade

World soyabean production has been rising steadily from 80 m tonnes in 1980/81 to 130 m tonnes in 1996/97. The four biggest producers are the US (49%), Brazil (20%), China (10%) and Argentina (9%). World trade in soya beans and soya products is even more concentrated, 65% of exports originating in the US and 23% in Brazil. Most soyabeans are crushed to produce meal and oil. Trade occurs in whole beans, oil and meal. Direct food use of soyabeans has been and is currently relatively small and stable at 9-10 million tonnes a year world-wide. This is concentrated in Asia where soyabeans are processed mainly into tofu-type and soy sauce products.

Soya is generally traded as a commodity crop (see sub-section 2.1) in which there is limited and simple grading. For example, Table 3.1 shows the main current US soyabean grades and requirements.

Table 3.1: Current US soyabean grades and grade requirements

	Minimum	Maximum				
Grade	Test weight (lbs/bushel)	Heat damaged kernels (%)	Total damaged kernels (%)	Foreign materials (%)	Splits (%)	Soyabeans of other colours (%)
US No.1	56.0	0.2	2.0	1.0	10.0	1.0
US No.2	54.0	0.5	3.0	2.0	20.0	2.0
US No.3	52.0	1.0	5.0	3.0	30.0	5.0
US No.4	49.0	3.0	8.0	5.0	40.0	10.0

Nevertheless, there are also a few non-commodity or value-added elements of the market[17] that derive from different soya varieties that can be grown or associated with specific end uses. In these markets demand tends to be more inelastic (ie, is less price responsive) than for products traded via a typical commodity system.

Some of the main soya-specific, value-added market segments of note (excluding consideration of GM soya: see later) are:

- *soyabeans used for tofu.* This segmentation is based on particular varieties of soya and details of this market segment's requirements are discussed further in Appendix 1. Clearly such varieties are required to be traded and transported to end users separate from the more widely traded, commodity soyabeans. Such beans destined for the Japanese tofu market currently trade at a significant premium to the current commodity soyabean price;
- *soyabeans used in high value-added manufactured products such as soya-milk.* Whilst the authors have not been able to obtain details of a typical specification required by a soya milk manufacturer[18], we are aware that such soya is usually required to have been grown to organic standards and trades at a significant premium to commodity soyabeans.

The key point to note in relation to these segments of the soya market is that they effectively represent examples where forms of IP for specific types or varieties of soyabeans are already practised to meet the specific requirements of certain end users and markets. This is discussed further in sub-section 3.4 below.

3.3. Forces for change

Although the sub-sections above summarise the main features of the current market for soyabeans and derivatives, the markets are subject to change. The primary current force for change in the soyabeans and derivatives markets is the drive to add value to products.

The most common way in which crops such as soya have traditionally had value added is through yield improvements. This increases the ratio of returns to input costs and has been the major objective of traditional breeding of new varieties for many years. Also in this context, are breeding characteristics such as herbicide resistance which reduce the costs of growing crops and hence also improve the ratio of returns to costs. Herbicide tolerance may be derived using traditional breeding techniques, but increasingly the methods used are based on modern genetic techniques. The key point to note about this form of adding value is that it adds value through increased production/lower costs of production of the commodity crop

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[17] That account for a very small share of overall soya trade.

[18] There are very few such manufacturers in Europe and those approached felt unwilling to supply information on commercial confidentiality grounds.

rather than via the development of a specific trait/feature for which end users may be prepared to pay price premia. In the context of this report, these cost saving or revenue enhancing developments are not classified as ‘value adding’ changes.

The second main way in which value is being added to soya (ie, the developments that are considered to represent value adding in the context of this report) is via alteration of the inherent characteristics of soya so as to allow a premium to be charged. This strengthens the competitive position of the added-value product *vis-à-vis* its substitutable products. For example, the yield of conventional soya oil to meal is low compared to other oils, notably palm oil. Added-value traits are being researched and developed to increase the oil content and should therefore make soya oil more price competitive, and hence more attractive, compared to other oil sources (such added-value traits may also reduce the need for processing and may thus lead to processing cost savings).

Table 3.2 below illustrates some of the main, current value added aspects being researched and developed in respect of soyabeans. Whilst some of these are being researched using conventional plant breeding techniques, genetic modification and other modern biotechnological techniques figure prominently and have considerably shortened the time needed for the development of new varieties. The reader should note that Table 3.2 focuses on the development of new varieties containing compositional changes to soyabeans. Discussion of new products such as herbicide resistance ((a cost reducing technology) targeted at farmers) is presented in sub-section 3.4.2.

Table 3.2: Value-added soyabeans

Product	**Characteristics**	**Uses**
High lysine	Higher lysine content	Feed
Low stachyose	Improved carbohydrate profile and digestibility	Feed
High methionine	Higher methionine content	Feed, especially poultry
High stearic	Low trans fatty acids	Food, margarine and shortening
High oleic oil	Lowers blood cholesterol	Food
Low linolenic	Enhanced oxidative stability	Food, frying applications
Antibody containing	Favourable health features	Food, neutraceuticals, pharmaceuticals

The main current research focus is on increasing the protein and oil content, improving the amino acid profile, reducing or eliminating indigestible carbohydrates (raffinose and stachyose) and changing the characteristics of the oil. Although some of these research themes are being worked on in discrete, isolated steps by some, some traits can be and are being worked on simultaneously using biotechnology techniques.

3.4. Identity preservation and soya

The sub-sections above have highlighted the following key points:

- the vast majority of soyabeans produced in the world are traded via a commodity based system where there is limited grading and product is transported and stored in bulk (ie, in large volumes);
- there exist small market segments for specific end uses (notably organic soyabeans and specific varieties to service tofu requirements). In order to service these market segments, IP is required of the appropriate soyabeans;
- there is a premium price for soyabeans that meet the requirements of the specific market segments over the price for commodity soya;
- in all of the soya market segments where IP occurs, the specifications laid down by end users have tolerances (eg, for percentage of extraneous material);
- the trend for developments in the markets for and use of soyabeans is towards increased value adding. This implies greater development of specific market segments (where IP occurs) within the overall market for soyabeans and decreasing importance for non-identity preserved, commodity traded soyabeans.

There are examples of the application of gene technology to the soyabean sector in both of the main categories defined in sub-section 2.2:

- Modifications aimed at consumers through v*alue adding.*
- Modifications aimed at farmers through a*gronomic traits* which increase expected farm profitability (by reducing costs, increasing yields, reducing risk).

Each of these is discussed further below.

3.4.1. Modifications aimed at consumers -value adding traits

As indicated in Part I (section 2.2.1) the scope for development of such products depends on the value adding traits being perceived to be of value to end users who would then be prepared to pay price premia for such traits. On the supply side, those involved in the production and supply of value added, GM soyabeans must maintain the integrity of the product throughout the supply chain using IP. Therefore, such products cannot be traded through the commodity market system applicable to mainstream soyabean trade. This means that the price premia paid by end users has to be sufficient to cover the additional costs of initiating the IP. In the course of this research, the authors were able to identify some examples of IP in respect of value-added soyabeans. The details are presented in Appendix 1 (examples of IP). The key features are:

a) *Objective*: development of soyabeans in the US containing value-adding traits such as low inolenic, high oleic, low saturate, high protein and high sucrose soyabeans. Some of these are with and some without the use of GM technology.
b) *Specifications and requirements*: detailed IP requirements at the farm, elevator, processor and refiners.
c) *Costs and price premia*: these were:
   - farm level: $9-10 per tonne (about 4% premia on average ex-farm soyabean prices in 1997). This included provision to cover lower yields of the value-added soyabeans relative to conventional soyabeans;
   - elevator level: $1.80 to $3.70/tonne
   - processor level: variable by mill according to size, capacity and throughput. Broadly $1.80 to $3.70/tonne;
   - refiner level: $4.40-$8.80/tonne, depending on the need for using additional separate storage tanks and additional clearing.
d) Overall, the total cost is within a range of $17-26/tonne. It is however difficult to compare this to the cost of production using conventional soyabeans because actual costs incurred vary by processor, these costs are commercially sensitive and once processing has begun, the soya derivatives are used in many different products all with different prices. Relative to the cost of soyabeans at the farm level, the total IP cost is equal to about 6-9% of the average 1997 US farmgate price of soyabeans.

3.4.2. Modifications aimed at farmers -agronomic traits.

In Part I, section 2.2 it was highlighted that for this category of GM, there is no economic incentive for suppliers to initiate IP and labelling of GM crops, and only a (probably limited[19]) legal requirement to label some products as containing GM. Not surprisingly, the authors have not identified any instance of IP having been initiated for GM soyabeans containing or derived from soyabeans genetically modified for agronomic traits.

However, the authors did identify a number of instances where food manufacturers and retailers have been willing to pay premia to suppliers at earlier points of the supply chain to initiate IP and supply non-GM soyabeans and derivatives. An important point to recognise about these examples which are summarised in Table 3.3 and presented in more detail in Appendix 1, is that the premia paid by these companies has, as far as the authors are aware, not been passed onto consumers in the form of higher prices. The costs have been absorbed by the processor because of a desire, presumably, to assure all customers (some of whom may be concerned and wish to avoid such products) that their products do not contain soya derived

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[19] Under current EU labelling requirements.

from varieties based on GM (herbicide resistant) technology. The willingness of these companies to ‘sink’ the costs of obtaining ‘IP’ non-GM soya can be attributed mainly to the nature of the end products made from these soyabean ingredients (having a fairly elastic demand) and the relatively small contribution made by soya or soya derivatives in the total cost and composition of a further processed product. For example, soya ingredients such as protein meal and lecithin account for a very small proportion of the total costs for manufacturing chocolate.

The above examples illustrate that IP is currently being used for soya derived from non-GM beans containing an agronomic, cost saving trait. The costs associated with this IP are small relative to the total production costs and value of the end products. It is therefore reasonable to pose a question about the scope for, and willingness of those in the supply chain to provide IP for lower value-added products’ (for which demand tends to be more responsive to price changes) and for products where soya is a significant ingredient. For such products, the willingness to absorb IP costs is likely to be lower given the relatively higher impact on their cost base and the more responsive nature of demand for their produce. Inevitably these additional costs would have to be passed on to the consumer (the precise proportion that would be passed on will depend on the elasticity of demand and the level of competition in the market). Currently, it is difficult to predict how much additionally they might be willing to pay and how many consumers might fall into such a market segment.

3.5. Summary and policy considerations

The key points concerning the examples of IP of non-GM soya are as follows.

There are additional costs associated with the IP process. These mainly concern costs of testing and IP post-farmgate, ie, the costs fall mainly at the processing and transport phases. These include some capital (start-up) costs and some additional running costs. Ultimately the additional cost relative to use of commodity sourced soya varies according to the ingredient and use made of the soya derivatives. Consequently it is difficult to ascertain whether these additional costs will be passed onto final consumers in the form of higher prices (see sub-section 2.4 for discussion of factors influencing this). The limited time that has so far elapsed since this IP sourcing has been initiated is such that the respective instigators of IP have been willing to absorb the costs in the short term. In the longer term, it is difficult to predict what will happen.

There is evidence that, as expected, the costs of IP (post-farmgate) decline once set-up costs are observed and the market participants benefit from learning by doing.

Table 3.3: Summary of key features of case study examples of IP of non-GM (herbicide resistant soyabeans)

	Case study 1	Case study 2
Objective	Obtain non-GM soyabeans as a source of protein for use in processed products (chocolate) for an EU food manufacturer	Source non-GM soyabeans to be used as a raw material for ingredients in the manufacture of processed products for an EU retailer
Requirements and specifications	Farm level: - planting of non-GM varieties (contract grown); - strict IP on farm storage, transport and handling of beans; - cleaning and use of separate storage conditions; - prohibition of co-mingling with other soyabeans; - rigorous testing at each stage of supply chain; - cleaning, segregation and traceability at crushing facility.	Use of a completely closed system: - dedicated processing near point of production; - contract growing of specific non-GM varieties; - prohibition on GM soya entering the transport and processing system or being grown by farmers; - testing prior to harvest.
Tolerances	100%, no detectable presence of foreign DNA or protein allowed	0.1-1% presence of GM material tolerated. Target = 0.1% or less, guaranteed minimum = 1% or less.
Cost implications	+150% to cost of supplying conventional 'non-IP' soyameal protein. However, this ingredient accounted for a very small part of total ingredient costs.	For lecithin +$0.8/tonne relative to general lecithin prices of $640-$1,600/tonne, delivered end user. A very small increase in cost but note ingredient represents only about 0.5% of total ingredient weight in chocolate.
Other points of note	Premia paid included need to offset lower protein content of soyabeans from this region relative to soyabeans available via the commodity traded system. Cost partially offset by premia available from selling non-GM soya oil.	The need to avoid possible use of soya oil containing GM, was dealt with by reformulating products to include sunflower or rapeseed oil. This increased the cost of ingredients but no figures per tonne were provided to the researchers.

The availability of non-GM soya relative to GM soya has an important influence on IP costs. Currently GM soya varieties account for about 35-40% of all soyabeans planted in the US and a significantly lower share of soya output in the other main producing countries (eg, Brazil, where to date authorisation of herbicide resistant GM soya was only given in the summer of

1998). Overall, the global GM soya area of 14.5 million hectares accounts for about 20% of the global planted area in 1998. This means that currently non-GM soya varieties account for the majority of world production and therefore set the baseline for world soyabean and derivative prices, traded through commodity-based systems. In the medium term however, if GM soya varieties continue to expand their share of overall production as they have in the US over the last 3 years, a position may soon be reached whereby GM soya production accounts for the majority of world production and traded soyabeans. At this point, the GM soya may set the baseline for commodity traded price of soyabeans. Given that GM soya varieties offer significant production cost savings to growers (estimated to result in 10-40% savings on herbicide applications costs, improved weed control and resulting in a cleaner crop[20]), this domination by GM soya could occur within a few years. Should this occur, it is likely that the benefits of the cost saving will be passed on down the supply chain in the form of lower real prices for commodity traded soyabeans. Thus, the baseline price for all soyabeans, including non-GM soya will effectively be set by GM varieties at a lower real level than currently prevails. The net effect of this would be to make the growing of non-GM soya varieties (with their higher production costs) less attractive to soyabean farmers unless purchasers of beans (in the processing and users sectors) were willing to pay a premium price for non-GM varieties.

In short, the examples presented illustrate that IP of non-GM soya is taking place and incurring some additional costs relative to soya supplied through the commodity system. This has been relatively easy to do because non-GM soya is widely available; indeed, non-GM soya currently sets the baseline for world soyabean prices. In the medium term, however it is reasonable to assume that the availability of non-GM soya may diminish and real soyabean prices may fall. The baseline prices may be set by GM varieties with their lower costs of production. Should this occur, a premia will be required by producers to grow *non*-GM varieties. This is likely to result in real increases in the cost of IP GM-soya relative to current costs. In the long run, some of this will probably be passed down the supply chain in the form of higher consumer prices for non-GM soya products and derivatives. It is however not possible to estimate what level or to what extent this may occur.

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[20] Whilst the precise benefits can be argued over, based on empirical evidence, what cannot be disputed is the rapid take up of the technology by US soyabean farmers who consequently must see a significant benefit, otherwise the take-up rate would probably be much lower This is in effect a classic example of the treadmill effect discussed in sub-section 2.4.2.

4. Maize

4.1. The usage of maize

Maize is a widely used crop which provides a major staple food for parts of Asia, Africa and South America. For human food use maize is ground into meals which are then used to produce a variety of products. White, yellow, flint and dent maize are all used for food. World food uses of maize currently represent about 27% of total use. Maize is also a major feed grain in many countries, its world-wide use in animal feeds accounts for about 50% of total grain usage. Maize is a preferred feed grain because it is rich in highly digestible carbohydrates and is therefore a major source of energy. It is also relatively low in fibre (important for pigs and poultry), and contains a modest amount of protein. The share of maize in total grain used for feeding varies around the world. It is highest in those countries where maize is either a major production crop, or represents a high proportion of imported grain for feed. It is less important in countries or regions of the world (eg, Europe) where other grains such as wheat, barley and sorghum are widely grown. The reader should refer to Appendix 4 for further information on the use and production of maize.

Maize also has many industrial uses. It is a relatively competitive raw material for manufacturing high quality starch that in turn can be used to make a variety of industrial products such as: food and industrial starches; a range of sweetener products; ethanol; citric and lactic acids; lysine; and monosodium glutamate (MSG). In addition, maize is widely used in pharmaceutical products, nutraceutical food products and industrial oxychemicals. The industrial use of maize is highly concentrated in a few countries, notably the US (60%), Japan and Korea (15%) and China and the EU (nearly 25%). Industrial use of maize currently amounts to about 65 million tonnes globally.

There are two ways to process maize for industrial use- dry and wet milling. Dry milling yields starch and distillers dried grain (DDG) which is used as animal feed. Wet milling extracts the starch and also produces two protein feeds (maize gluten meal, 60% protein and maize gluten feed, 21-22% protein), and maize oil. Wet milling is the dominant process used in the industrial processing of maize

Maize faces competition in its various usage markets from a variety of other products.

a) In animal feed

Cereals are major ingredients used in animal feeds and as such, each cereal tends to have a degree of inter-changeability as a raw material ingredient (ie, demand is fairly price responsive). This means that the price of each cereal relative to others plays a major role in determining usage levels in the animal feed sector. Nevertheless, whilst price tends to be the most important factor influencing specific cereal incorporation levels in animal feeds, factors such as digestibility and fibre content are also of significance.

b) In industrial uses

The main industrial uses of maize are based to a large extent on fermentation processes. Whilst maize is the main raw material used for fermentation in the US, other raw materials are important in other parts of the world. In Europe, wheat is the most important raw material used for making starch. In Asia, molasses and manioc are widely used to produce many of the industrialised products that are made from maize in the US. These differences in the relative importance of different raw materials for industrial uses effectively mirrors the relative price of each cereal in different parts of world.

c) Oil

As discussed in the soya case study, potential uses of vegetable oils depend largely on the characteristics of the constituent fatty acids and some differences in taste and shelf life. As such, maize oil technically competes with oils derived from a variety of oilseeds. However, because of the low oil content of maize relative to oilseeds, maize oil is more expensive to produce than most other vegetable oils. Hence, its use tends to be limited to higher value, premium markets where its price is less important a factor in determining demand for the product.

4.2. Maize production and trade.

World maize production has grown steadily from just over 400 million tonnes in 1980/81 to 580 million tonnes in 1996/97. The US is the largest world producer of maize (its share in 1996/97 was 41%), producing twice the amount of China (share 18%), the second largest producer in the world. In terms of global trade in maize, the US is also the largest source of traded maize (70% of total world maize exports), followed by Argentina (15%).

Like soyabeans, maize is generally traded as a commodity crop (see sub-section 2.1) and is subject to limited grading. For example, in the US, the maize grade US number 1 has limits of a maximum of 3% for total damage to grains, 2% for broken maize and foreign material, and a test weight minimum of 56 pounds per bushel. However, there are also a few non-commodity or value-added elements of the market[21] that derive from different maize varieties that can be grown and/or associated with specific end uses. Some examples include:

- *waxy maize*. This market segment is based on particular varieties of (waxy) maize that possess desirable qualities and characteristics of value in the manufacture of modified starches used in processed human foods (waxy varieties are over 99% amylopectin content compared to 72-76% amylopectin and 24-28% amylose content in 'commodity'
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[21] That account for a very small share of overall maize trade.

maize). The majority of this crop is grown on contract by farmers for specific end users and hence the crop is identity preserved from farmgate to end user and does not enter the commodity-based trading systems applicable to most maize varieties. Waxy maize traded at a price premium of about $10-$12 per tonne over the average commodity US farm level maize price in the 1997/98 marketing year of about $114/tonne;

- *white maize*. This segment is also based on specific varieties of white maize which are favoured for human consumption in some countries (notably in Southern Africa) and for specific processing uses such as alkaline processing for food use. About half of the white maize crop in the US is grown on contract with the crop essentially subject to IP or segregation from other maize varieties from harvest to end purchaser. White maize in the US tended to trade at a price premium of about $18-$21 per tonne over commodity maize (US farm level prices in 1997/98);
- *hard endosperm maize*. This segment is based on specific varieties of maize which have a high amount of vitreous endosperm relative to the amount of flour endosperm. This allows higher yields of grits when milled and is of value to manufacturers of products such as snack foods. Very little of this maize is grown on contract but the crop is subject to IP from other maize varieties from harvest to end purchaser. This maize traded at a price premium of about $2-$8 per tonne over commodity maize (US farm level prices in 1997/98).

4.3. Forces for change

Although the sub-sections above summarised the main features of the current market for maize, the market is subject to change. Feed, food and industrial users of maize increasingly want more uniform quality with functional characteristics that suit their specific requirements (eg, starch content, quality and specific oil characteristics). This is because increased uniformity and special characteristics significantly improve processing efficiency, in what is typically a capital intensive industry and where it is estimated that between 20 and 30% of all capital investment in a modern US maize processing facility is purely to handle variability in the quality and functionality of the maize processed[22]. It therefore follows that being able to obtain more uniform quality maize with enhanced functionality can substantially reduce capital investment requirements, improve capacity utilisation and increase profitability.

Currently, the main value adding developments in maize being researched are summarised below in Table 4.1. Whilst some of these are being researched using conventional plant breeding techniques, genetic modification/modern biotechnological techniques figure prominently in these developments. It should be noted that discussion focuses on value

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[22] Source: Feedstuffs, March 10, 1997.

adding through changes to crop constituent parts rather than agronomic traits such as herbicide or insect resistance. These aspects are discussed further in sub-section 4.4.2.

Table 4.1: Value-added maize

Product	Characteristics	Uses
Waxy	Starch over 99% amylopectin [1]	Food and industrial starches
High amylose	Amylose content > 50%	Wet milling, mainly for industrial starch use
High starch	Extractable starch yields > 70%	Wet milling
High oil	Oil content > 5.8% [2]	Animal feed, replaces animal fats
High lysine	Reduces need for protein meals or synthetic lysine	Animal feed
High amino acid	Increased amino acid content	Animal feed
White	Whiter starch	Dry milling for food
Blue	Blue kernel	Dry milling for food
Hard endosperm	High amount of vitreous endosperm	Dry milling for food

[1] The starch in normal maize has 72-76% amylopectin and 24-28% amylose.

[2] Normal maize oil content is 3.5%. High oil maize also has a greater protein content.

Within this list, the most prominent areas of new (value added) development stem from:

- better understanding of the role of amino acids in animal nutrition which first led to the production of synthetic amino acids. Researchers are now focusing on raising the amino acid content of maize;
- the recent rapid growth in production of high oil maize responds to user needs for a higher energy maize which also contains more protein;
- developments in starch production technology which has increased the demand for maize with higher starch content.

As illustrated in the soyabean case study, the drive to develop new, added value products and the opportunities offered by both technology provides scope for developing new maize varieties containing multiple new traits.

4.4. Identity Preservation and maize

The sub-sections above have highlighted the following key points:

- the vast majority of maize produced in the world is traded via a commodity system;
- there exists small market segments for specific end uses (eg, post-harvest chemically free maize: see Appendix 1). In order to service these market segments, IP is required of the appropriate maize from mainstream commodity maize;

- maize that meets the requirements of the specific market segments trade at a premium to mainstream maize. These premia largely reflect the additional costs involved;
- in all of the maize market segments where IP occurs, the specifications laid down by end users have tolerances (eg, for percentage of extraneous material);
- the trend for developments in the markets for and use of maize is towards increased value adding. This implies greater development of specific market segments for which IP is necessary within the overall market for maize and decreasing importance for non-identity preserved, commodity traded maize.

There are examples of the application of gene technology to the maize crop in both of the two categories defined in section 2.2.

- Modifications aimed at consumers through *value adding*.
- Modifications aimed at farmers through *agronomic traits* which increase expected farm profitability (by reducing costs, increasing yields, reducing risk).

Each of these is discussed further below.

4.4.1. Modifications aimed at consumers - value adding traits

As indicated in the soyabean crop case study the scope for successful development of such products depends on value adding traits being perceived to be of value to users who in turn would then be prepared to pay price premia for these traits. These premia must also adequately cover any additional costs associated with the IP. Our research identified three main examples of IP occurring for value added maize and these are presented in detail in Appendix 1. A summary of their key features is shown in Table 4.2.

Table 4.2: Summary of key features of IP of value added maize

	Case study 1	**Case study 2**	**Case study 3**
Objective	Supply and IP high oil content maize in the USA.	Supply and IP high oil content maize in Europe.	Supply and IP waxy maize grown in Europe.
Requirements and specifications	Contract growing with farmers. Specifications for cleaning of storage, transport and delivery to specified processors. Specifications for storage, cleaning, no co-mingling and testing at elevator and at miller levels.	Almost identical to case study 1.	Almost identical to case studies 1 and 2. Additional points include isolation in the field to avoid cross-pollination, use of separate storage on-farms and for transport.

	Case study 1	**Case study 2**	**Case study 3**
Costs or premia paid	Farm level: not fully disclosed. IP costs estimated at about $6/tonne (5% premia on average ex-farm maize prices in 1997) but additional (undisclosed) premia required to offset lower yield of varieties relative to conventional lower oil content maize. Elevator level: $1.2-$2.00/tonne Miller level: varies by mill due to size, capacity and throughput Estimated: $10.00/tonne.	Farm level: not disclosed. Elevator level: $20/tonne (17% of farm level price of commodity maize in 1997). 40% of this estimated to be for reduced yield and the balance for IP costs. In some cases all premia is passed back to the farmer, in other cases co-operatives retain some proportion.	Farm level: premia of $170/ha to compensate for IP lower yield (10-15% drop relative to conventional maize) and isolation. Transport: $3.6-9/tonne or 2-5% of the farmgate price of maize. Additional test costs not disclosed but indicated to be relatively small.
Tolerances	Yes: customer specific but not disclosed	As case study 1.	As case studies 1 and 2.

4.4.2. Modifications aimed at farmers -agronomic traits.

The authors did not identify any examples of IP for GM maize containing agronomic traits such as the corn borer resistant maize for which information was made available[23]. Additionally, no instances of IP of non-GM maize were found. Nevertheless, the authors understand that some end users in the European food processing sectors may be requesting supplies of non-GM maize and paying premia for such products. At the time of writing (November 1998) no further information of any such development of IP non-Bt maize were made available to the authors.

4.5. Summary and policy considerations

The key points to note concerning the examples of IP for maize are similar to those for soya.

The bulk of maize is traded through the commodity system for relatively low-value uses such as animal feed. Some IP occurs for small specific markets of particular varieties of maize, and IP, specifically for non-GM maize for use in a range of products is probably beginning to occur.

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[23] In other words, the authors are aware that there are instances of IP occurring but were unable to obtain any information about these examples.

There are additional costs associated with the IP process. Unlike soya some maize needs to be grown in isolation to reduce the risk of cross-pollination. This constraint on the farmer imposes additional costs for maize compared to IP costs for soya at the farm level. There are also additional costs post-farmgate (in transport and processing costs).

Looking forward, the same issues concerning the motive for adoption of new agronomic GMOs referred to in the soyabean case study (see sections 2.4.2 and 3.4.3) will be applicable for maize. Similarly the incidence of the IP costs between farmers, processors and consumers will be subject to the same forces as for soyabeans. The rate at which these developments occur will depend on the advantage conferred by the modifications, and thus the speed of uptake of GM maize (in 1998, 8.3 million hectares of GM maize were planted globally, of which 6.5 million hectares were in the USA), the costs of IP and the sensitivity of demand both to prices and to the presence of labels indicating GM.

As in the soya case, the data presented for the case studies of IP which are already in existence show a wide range depending on the extent of the IP and the nature and size of the market. It is difficult to extrapolate from these results the likely costs per tonne of any generalised IP of maize that might occur (eg, for the animal feed market).

5. Oilseed rape

5.1. The usage of oilseed rape

Oilseed rape provides a source of both oil and protein meal that is used in food, animal feed and industrial applications. Oilseed rape is used as an ingredient or raw material for many of the same products that use soyabeans. There is no direct food use of oilseed rape. The seeds are crushed to provide its primary constituent parts of meal and oil which account for approximately 60% and 40% respectively of the total content. As with soyabeans, meal is used mainly in animal feed and the oil is mainly used for human consumption (salad oil, margarine and shortening) and industrial purposes (industrial oil, bio-diesel, paints, varnishes, polymers, pharmaceutical, lubricants and surfactants).

As a feed ingredient, oilseed rape meal (or cake) is considered to have a high protein, good energy profile that competes with soyabean meal. However, its protein content is lower and is less digestible and consequently tends to be sold at a price discount relative to soyabean meal. Oilseed rape accounts for 12% of total protein meal used globally compared to about 60% for soyabean meal.

Both rapemeal and rape oil are used for industrial purposes. Rape oil is used mainly in the production of resins, plastics, paints, varnishes, polymers, pharmaceuticals, lubricants, surfactants, ink and as bio-diesel. The proportion of rape oil used for industrial purposes has been increasing steadily over the past thirty years and currently accounts for about 13% of all oil used in industrial applications. Approximately 100,000 hectares of erucic acid oilseed rape are grown annually for industrial purposes in the EU. Rapemeal has also traditionally been used in the manufacture of fertilisers, although the range of uses has broadened over the last ten years.

Like soyabeans, oilseed rape faces competition from other sources of oil and meal (ie, demand for oilseed rape is fairly price responsive). Rapeseed oil is used for similar purposes to soya oil but, largely because of its low level of saturated fat, it sells at a price premium to soya oil in many markets. Its main competitors in European markets are the same as those for soya (Chapter 3) namely soya oil, sunflower oil, olive oil and groundnut oil.

Meals derived from oilseeds are important ingredients, especially as a source of protein, in animal feeds. In this market, the largely interchangeable nature of these different protein sources means that the relative price of each protein source is the key determinant of actual usage although each meal also has specific nutritional values. Rapemeal is the second most widely used oilmeal as a protein source in animal feeds. This can mainly be attributed to its price; as indicated above it sells at a discount to soyabean meal although it is becoming a preferred source of protein in ruminant rations because its protein is rumen degradable.

5.2. The oilseed rape market

World oilseed rape production in the 1990s has fluctuated in the range of 25 million tonnes to 30 million tonnes. Rapeseed currently accounts for around 12% of total world oilseed production. However, the relatively high oil content in rapeseed (60%) means that it accounts for about 15% of world vegetable and marine oil utilisation.

The major world producers of oilseed rape are China (29%) the EU (25%), Canada (18%), and India (18%). However, Canada is the largest world exporter accounting for more than three-quarters of world trade in this commodity.

Like soyabeans, oilseed rape is generally traded as a commodity crop (see sub-section 2.2). However, there are also some value-added segments developing within the market where IP of specific types and varieties is becoming important. This is discussed further below.

5.3. Forces for change

The main forces for change in the markets and use of oilseed rape are very similar to those affecting the soyabean and maize markets. There is a drive to increase the revenue or unit value of rapeseed products principally through two routes described below. These are summarised in Table 5.1.

a) *Yield improvement* has been the major focus of most traditional plant breeding programmes applied to oilseed rape varietal development. Simultaneously, the development of varieties low in euric acid and glucosinolates has also been a priority breeding during the last two decades. The current targets are improve yields and lower costs of production through the development of new hybrid varieties, and to produce herbicide resistant and fungal resistant oilseed rape varieties using the technology of GM.

b) *Adding value through quality traits.* Current developments in altering the composition of oilseed rape have focused on developing rapeseed with higher phytase content which would improve the crop for animal feed uses and to modify the oil content and mix to offer specific end user benefits in the human food markets. Examples of the latter are lower trans-fatty acid composition and enhanced oxidative stability for cooking.

As with both maize and soyabeans, the drive to develop new, added value products and the opportunities offered by GM technology provides scope for developing new varieties containing multiple new traits.

Table 5.1: Value-added oilseed rape

Product	**Characteristics**	**Uses**
Molecular hybrids	Higher yielding	Any
Glufosinate, glyphosate and bromoxynil resistance	Herbicide tolerant	Any
Increased phytase content	Improved feed conversion	Feed
Inclusion of polymers, enzymes		Industrial
High laureate	Modified fatty acid composition	Feed and food
High sterate	Modified fatty acid composition	Feed and food
Fungus resistance	Fungus resistance	Any

5.4. Identity Preservation and oilseed rape

The sub-sections above have highlighted the following key points:

- almost all oilseed rape is traded via a commodity system;
- a few small, niche (value-added) segments exist in the market for oilseed rape (eg, organic, high laureate). These are recent developments. In order to service these market niches, IP is required of the specific oilseed rape relative to mainstream commodity trade oilseed rape;
- this is also an important industrial market segment for high erucic acid oilseed rape which must be kept out of any commodity supply chain that may service human food markets;
- the trend for developments in the markets for oilseed rape is towards increased value adding. This implies greater development of specific market segments where IP will be necessary. There will be a concomitant decline in importance for non-IP, commodity-traded oilseed rape.

There are examples of the application of gene technology of oilseed rape in both of the main categories defined in section 2.2.

- modifications aimed at consumers through *value adding*.
- modifications aimed at farmers through *agronomic traits* which increase profitability (by reducing costs, increasing yields, reducing risk).

Each of these is discussed further below.

5.4.1. Modifications aimed at consumers - value-adding traits

The scope for successful development of such traits depends on the value-added traits being perceived to be of value to users who in turn will be willing to pay price premia for them. This implies:

- the integrity of the GM product is maintained throughout the supply chain, using IP;

- additional costs will be incurred in setting up and maintaining the IP that do not occur in the commodity-based system of trading;
- the participants in the supply chain will only undertake the production and supply of value-enhanced oilseed rape if the additional costs referred to above are adequately covered by price premia paid by users.

The authors were only able to identify one example of IP occurring for value-added oilseed rape, although a related example was found for sunflower. Details of these two cases are presented in Appendix 1 and summarised in Table 5.2.

Table 5.2: Summary of key features of IP of value added sunflower and oilseed rape

	High oleic sunflower	**High laureate oilseed rape**
Objective	Supply and IP high oleic sunflower in the US.	Supply and IP high laureate oilseed rape.
Requirements and specifications	Contract growing with farmers. Specifications for seed varieties to use, cleaning of storage and transport and delivery to specified processors. Specifications for storage, cleaning, no co-mingling and testing at elevator, processor and refiner level. Also some separate storage at processor level.	Almost identical to high oleic sunflower.
Costs or premia paid	Farm level: not fully disclosed. IP costs estimated at about $10/tonne (4% premia on average ex-farm sunflower prices in 1997) but additional (undisclosed) premia are required to offset lower yield of varieties relative to conventional, lower oleic content sunflower. Elevator level: not disclosed but not perceived to be significant. However, sunflower, as a minority traded crop (relative to soya) has high unit transport Processor level: see elevator level Refiner level: see elevator level	Farm level: $15/tonne plus no transport costs from farm to processor. Other levels: no information provided.
Tolerances	Yes: customer specific but not disclosed.	Yes: customer specific but not disclosed.

5.4.2. Modifications aimed at farmers – agronomic traits.

The authors identified one example of positive IP for GM oilseed rape (herbicide resistant). Details are presented in Appendix 1 and Table 5.3.

Table 5.3: Summary of key features of IP of value added oilseed rape

Objective	Initiate IP to ensure that GM OSR did not enter distribution channels servicing export markets outside North America.
Requirements and specifications	Contract growing with farmers. On farm use of separate storage and handling. Separation, cleaning and use of separate storage and transport. Cleaning and separation at crusher level. Administration, testing and monitoring.
Costs or premia paid	Farm level: \$0.73/tonne Transport/elevator level: \$6.6-\$8.8/tonne Processor/crusher level \$2.2-\$3.67/tonne Administration: \$3.67/tonne Total cost = \$13.2-\$12.87/tonne or 6-8% of the 1996 farm gate price of OSR in Canada
Tolerances	None set.

5.5. Summary and policy considerations

The main features of IP as applicable to GM oilseed rape to date are as follows.

The additional costs associated with the IP process are similar to those presented in the soyabeans and maize sectors.

GM oilseed rape containing herbicide resistant genes grown in Canada was subject to IP from the farm level through to the crushing and processors. Essentially, the GM crop was being actively subject to IP in order to avoid co-mingling with commodity traded oilseed rape. However, purchasers did not pay any difference in price compared with the commodity traded product. Indeed, the purchasers of the GM oilseed rape expressed no preferences (positive or negative) for GM oilseed rape or non-GM oilseed rape. This example of IP differs significantly to the examples of herbicide resistant soyabeans. In the soyabean case, users initiated the IP of conventional varieties, whereas in the oilseed rape case, the IP applied to the GM variety and was initiated by the suppliers of the technology and the primary producers to ensure that GM oilseed rape did not enter the commodity-traded oilseed rape export market. The IP was also of a short term nature and discontinued once approval for import of GM oilseed rape had been granted in the main export markets outside North America.

For the future, the same issues highlighted for soyabeans and maize will also apply to oilseed rape. A market segment of IP non-GM oilseed rape may develop. However there are some important differences between oilseed rape and soyabeans and grain maize. First, oilseed rape is relatively less important (and visible) than the other two crops. Second, the penetration to date (world-wide) of GM varieties of this crop is lower than for soyabeans (2.4 million hectares or about 10% of the 1998 global oilseed rape area were GM varieties). Third, there is currently a great nervousness about releasing GM oilseed rape in Europe with moratoria on the commercial release being discussed in France, and the UK. In these circumstances there may be greater pressure for a requirement of IP for the GM crop to allow consumers the opportunity to avoid it. The costs of this are not easily assessed on the basis of the evidence presented in the above case studies.

Appendix 1: Examples of IP

A1.1. IP in conventional soyabeans

Objective
To supply the Japanese market with an Identity Preserved soyabean.

Key features of the contract specification are as follows:

- seed variety has a large kernel and high protein content which allows it to compete with Japanese-grown varieties in terms of both appearance and inherent characteristics;
- IP is handled by both the farmer and a contracted screening company. Once the beans have been screened they are bagged to comply with Japanese food grade quality;
- traders are required to ensure that the beans meet the required contractual quality standards;
- quality, handling and destination are identified and handled so as to be identifiable to farmer lot;
- shipping is using sealed containers.

The beans sell at a significant premium over commodity based soyabeans. This premium is paid on delivery and provides 'compensation' for the additional costs incurred. The premium is agreed as part of the contract and is therefore dependent on a range of factors prevailing at the time. The level of premium was not provided, being commercially confidential.

A1.2. IP in value-added GM soyabeans

Objective: Development of soyabeans containing value adding traits such as:

- low linolenic soyabeans;
- high oleic soyabeans;
- low saturate soyabeans;
- high protein food grade soyabeans;
- high sucrose soyabeans.

The supply chain IP requirements in order to retain the integrity of the traits of the above include the following:

a) Farm level
Farmers/growers are required to undertake (via contracts to supply) the following:

- plant the specified seed product as stipulated in the contract;
- clean planter boxes prior to planting;
- provide a field map detailing where the product has been planted;
- clean combine prior to harvest;
- clean storage bins if on-farm storage is to take place;
- clean trucks/wagons/augers prior to transporting IP crops;
- deliver the IP production to designated elevator or processor at harvest.

Currently US soyabean growers who have contracted to produce soyabeans containing some of these value-added traits are paid premia over commodity based soyabeans. These premia (which were not disclosed to the researchers) clearly compensate for the additional costs of the above IP requirements, but also take into consideration the fact that these new varieties containing value-added traits produce lower yields than conventional soyabean varieties. In respect of the IP costs alone, however, the organisation involved in contracting with farmers to grow the value-added soyabeans indicated that the premia needed to cover this element of the additional costs was about 9-10 US dollars/tonne (ie, about a 4% premia on average ex-farm soyabean prices in 1997).

b) Elevator level

The oilseed elevator is required to comply with the following IP requirements:

- clean storage bins prior to the acceptance of the IP crop;
- ensure that there is no co-mingling during unloading or storage of these varieties with other soyabeans;
- sample and test each load prior to unloading to ensure that quality specifications are met;
- deliver the IP production to the designated processor or export terminal specified in the contract.

The premium paid to elevator operators to cover the additional costs involved is estimated to be between $1.80 and $3.70/tonne.

c) Processor level

Oilseed crusher IP requirements include the following:

- ensure that storage tanks for products are clean prior to use;
- sample and test each load on arrival to ensure that quality specifications are met;
- ensure that there is no co-mingling during crushing. This can be done in one of two ways. Either the plant is thoroughly cleaned out between batches or some beans are run through the machinery and then discarded at the 'head' and 'tail' of each batch.

The associated costs of meeting these IP requirements varies from mill to mill, mainly because of size, capacity and throughput. A broad estimate of the additional costs involved relative to crushing of mainstream soyabeans is $1.80 to $3.70/tonne.

d) Refiner level

At this stage any additional IP requirements are likely to focus on the possible need to use additional (separate) storage tanks and/or for additional cleaning. The premium required to cover such additional costs is estimated to be within a range of $4.40 to $8.80/tonne.

Overall, the total IP cost up to refiner level is within a range of $17 to $26. It is however, difficult to compare this to the cost of production using conventional soyabeans because actual costs incurred vary by processor, these costs tend to be commercially sensitive and once processing has begun, the soya derivatives are used in many different products all with different prices. Relative to the cost of soyabeans the total IP cost is equal to about 6-9% of the 1997 farmgate price.

A1.3. Case study examples of non-GM (herbicide resistant soyabeans)

Example 1: Objective: Sourcing of non-GM soyabeans to be used in the manufacture of protein for use in processed products for an EU food manufacturer.

Production source: soyabeans are grown in the USA in a region for which suitable varieties containing GM herbicide resistance have not yet been made commercially available (1998). This mitigates against some potential problems in terms of co-mingling of GM and non GM soyabeans on-farm. Nevertheless, rigorous supply specifications and procedures have been set for supply of the products. These are detailed below.

a) The soyabean seeds used have to be guaranteed by the supplier (seed company) to be a traditional (ie, non-transgenic) variety.

b) The seller of the harvested beans is required to sign a legally binding contract guaranteeing that the beans are GMO-free. This is subject to three conditions:

- if analysis indicates that the buyer cannot use the soyabeans (as a result of co-mingling), the seller is obliged to fully refund the buyer;
- sampling for GMO analysis at arrival into European port;
- independent analysis.

c) There are a number of requirements relating to the storage, transport and handling of beans between the US and Europe (see also sub-section 3.3.1):

- strict IP of the beans with respect to handling and transportation (ie, no other commodity type beans that may have been derived from plants containing GM traits should be handled or transported at the same time);
- installations are cleaned and separate storage bins are used;
- documentation is required for each step to verify that cleaning of all equipment used for transport and storage has taken place.

d) Supervision of this process is split between the seller and the buyer as follows.

- under the supervision of the seller (who records the details for the buyer):
    - transport between the farmer and the co-operative;
    - transport from the co-operative to the elevator at the US harbour.
- under the joint supervision of the seller, buyer and independent inspectors:
    - transhipment from elevator to vessel;
    - inspection of vessel;
    - buyer's statement that storage and loading procedures have been properly documented and accounted to comply with good handling practice;
    - loading in vessel.

e) There is a prohibition on handling or transporting any other soyabeans or soyameal during transhipment and storage in Europe. The requirements are under the joint supervision of the seller, buyer and independent controller:

- installations are cleaned and separate storage bins are used;
- a statement signed by the seller, buyer, elevator operator and controllers is issued to confirm that the discharging and storing silos equipment were found in clean conditions and that they conformed to the seller and the buyer's requirements;
- a statement signed by the seller, buyer, elevator operator and controllers is issued to confirm that the discharging, sampling and storing were found corresponding to instructions.

f) A final analysis then takes place to confirm the GM-free nature of the soyabeans.

g) There are several requirements during crushing:

- cleaning of the facility under the supervision of the end user;
- no other soyabeans or soyameal are to be handled or transported at the same time or together with the IP soya;
- transhipment then takes place into cleaned and separate bins at the crushing plant;

- segregation and traceability is monitored by the end user;
- the processed soya is stored in cleaned and separate bins.

h) After crushing, the soya products are transport to the final processing plant. This involves the following:

- no other soyabeans or soyameal are to be handled or transported at the same time or together with the IP soya;
- loading installations and railway wagons are cleaned prior to loading.

i) Similar requirements apply at the final storage silos under the supervision of the end user:

- no other soyabeans or soyameal are to be handled or transported at the same time or together with the IP non-GM soya;
- unloading installations are cleaned prior to unloading;
- storage silos are cleaned;
- there are regular controls on the product to ensure that it is GM-free.

j) Transporting the products to the factory also takes place under the supervision of the end user. The process is as follows:

- load the soya products into cleaned railway wagons;
- transport to the factory and unload.

k) Due to the current lack of established and accepted tolerance levels concerning the definition of non-GM soya, the tolerance used by this end user is effectively 100%. In other words, the soya protein is only used if tests do not detect any presence of GM (ie, recombinant DNA or protein).

The above process increases the cost of supplying soyameal protein by about 150% (ie, on the basis of one tonne of soyameal protein derived from commodity soya which may contain GMOs costing about $276/tonne to the EU processor, the cost of an equivalent tonne of non-GM soya protein to the processor is about $411/tonne. These additional costs take into consideration the following:

- a need to purchase additional volumes of soyabeans to offset the lower protein content of the soyabeans from this region relative to soyabeans available via the commodity traded system;
- the premia available (as an offset to the overall additional costs) from selling GMO-free soya oil.

b) Example 2: Objective: Sourcing of non-GM soyabeans to be used as a raw material for ingredients in the manufacture of processed products for an EU retailer.

Production source: soyabeans grown in Brazil – a country for which varieties containing GM herbicide resistant soyabeans, and suitable for growing in Brazil have either not yet been made commercially available or given regulatory approval for planting (September 1998). This mitigates against some potential problems in terms of co-mingling of GM and non-GM soyabeans on-farm and further downstream.

Key features of requirements and specifications are detailed below.

a) A completely closed (end user specific) system has been established in which:

- a dedicated processing plant that is geographically and logistically isolated from the (possibly co-mingled) coastal port areas is used;
- this plant controls the process by supplying non-GM soyabean seeds to growers via a producer co-operative who plant and grow on contract to this plant;
- the processing plant only processes and uses non-GM soyabeans from this contracted, controlled and dedicated source of supply.

b) The main, additional costs associated with this form of IP supply of non-GM soyabeans include:

- capital or start up costs which are estimated to be about 16,000 US dollars (awaiting context of volume processed???);
- testing. Crop leaves are tested prior to harvest to ensure that the plants are free of GMOs at a cost of 6,400 – 8,000 US dollars for all production (awaiting details on volume processed). As the plant is dedicated, beans rather than the derivatives can be tested. This reduces the cost of testing. Additionally, the organisation operating the IP exercise indicated that there has been a 40% saving in operational costs in year two of operation relative to year one because of the benefits of having ‘gone down a learning curve’.
- an additional cost due to Brazilian soyabeans generally being more expensive than soyabeans available from other sources of supply (eg, USA). This was considered to be equal to paying about a 10% price premia for the beans themselves (note: reference price for soyabeans ex-farm in the US for 1997 (annual average) was 275 US dollars/tonne).

c) The system specifies that tolerance levels have been set at 0.1% and 1% for the presence of GMOs. Essentially, this means that products will ultimately be legally guaranteed to be a minimum of 99% non-GM soya although normal practice is to ‘shut down and investigate' the process if tolerance levels exceed 0.1%. Hence, this threshold acts as a early warning for investigation and the effective tolerance level is therefore 0.1% or 99.9% non-GM soya content.

d) One of the non-GM soya derivatives manufactured is lecithin. For this product the company initiating the sourcing and manufacture of the non GM product indicated that the additional costs of IP associated with the system added about 0.8 US dollars/tonne to the cost of manufacture. This should be seen within the context of lecithin selling at prices ranging between 640 US dollars/tonne and 1,600 US dollars/tonne, delivered end user (this wide range depends on the size of order, unit of supply (eg, in bulk or in units of 50kg buckets) and location in Europe of purchaser). Hence the additional cost compared to lecithin derived from soyabeans that may contain GMOs is very small in terms of the overall cost of the product. This should also be seen in the context of lecithin being a minor ingredient in chocolate where it accounts of only about 0.5% of ingredient weight.

A1.4. IP example applicable to conventional maize

Post harvest chemically free maize

Objective

To supply the Japanese market with an Identity Preserved maize that has not been treated with any post-harvest chemicals.

Key features of the contract specification are as follows:

a) Farm level

- only producers that have the highest integrity and the best record for delivering clean maize are approached;
- no chemical must be applied to the maize after harvest or to the bin in which it is stored;
- maize that is to be chemical-free must be stored separately from other maize;
- producers are approached when an export sale has been made and they ship maize against this sale if they agree to the price being offered. They are under no obligation to sell;
- random tests are made on the maize accepted into the programme.

b) River terminal

- grain bins to be used for storage are thoroughly cleaned prior to accepting the maize;
- the elevator, loading leg and conveyor belt are also cleaned prior to handling of the maize;
- the barge used for transport to the sea port is also cleaned in order to pass an inspection before loading commences, as is the elevator;
- samples are taken for independent analysis.

c) Export terminal

- barges are left unloaded until the export vessels has passed an inspection. If, however, barges do need to be emptied, the grain is stored in cleaned storage bins;
- all equipment used for loading and unloading is cleaned as at the river terminal;
- the contents of the barges are then loaded onto the export vessel with cleaned equipment and via a cleaned storage bin;
- several samples are taken every minute for analysis.

Premium

- there is a price premium equivalent to 16% of the normal price of non-segregated, commodity maize traded on world markets. Using recent (1997 averages farm level) maize prices as a base ($114/tonne) the post-harvest chemically free maize destined for the Japanese market sell for about $130/tonne.

A1.5. IP example applicable to high value (conventional) maize

Example 1: Objective: high oil maize grown in the US.
The supply chain IP requirements in order to retain the integrity of the trait include the following.

a) Farm level
Farmers and growers are required to undertake (via contracts to supply) the following:

- plant the specified seed product as stipulated in the contract;
- clean planter boxes prior to planting;
- provide a field map detailing where the product has been planted;
- clean combine prior to harvest;
- clean storage bins if on-farm storage is to take place;
- clean trucks/wagons/augers prior to transporting IP crops;
- deliver the IP production to designated elevator or processor at harvest.

Currently US maize growers who have contracted to produce high oil maize are paid premia over commodity based maize. These premia (which were not disclosed to the researchers) clearly compensate for the additional costs of the above IP requirements, but also take into consideration the fact that these new varieties containing value added traits produce lower yields than conventional maize varieties. In respect of the IP costs alone, however, the organisation involved in contracting with farmers to grow the value added maize indicated that the premia needed to cover this element of the additional costs was about 6 US dollars/tonne (ie, about a 5% premia on average ex-farm maize prices in 1997).

b) Elevator level
The elevator is required to comply with the following IP requirements:

- clean storage bins prior to the acceptance of the IP crop;
- ensure that there is no co-mingling during unloading or storage of these varieties with other maize;
- sample and test each load prior to unloading to ensure that quality specifications are met;
- deliver the IP production to the designated processor or export terminal specified in the contract.

The premium paid to elevator operators to cover the additional costs involved is estimated to be between $1.20 and $2.00/tonne.

c) Miller level

The IP requirements of maize millers include the following:

- ensure that storage tanks for products are clean prior to use;
- sample and test each load on arrival to ensure that quality specifications are met;
- ensure that there is no co-mingling during milling. This can be done in one of two ways. Either the plant is thoroughly cleaned out between batches or some maize is run through the machinery and then discarded at the 'head' and 'tail' of each batch.

The associated costs of meeting these IP requirements varies from mill to mill, mainly because of size, capacity and throughput. An estimate of the additional costs involved relative to milling of mainstream maize is $10.00/tonne.

Example 2: Objective: High oil maize in Europe

The supply chain IP requirements in order to retain the integrity of the trait include the following:

a) Farm level

Farmers/growers are required to undertake (via contracts to supply) the following:

- plant the specified seed product as stipulated in the contract;
- clean planter boxes prior to planting;
- isolate the field to avoid cross-pollination;
- clean combine prior to harvest;
- clean storage bins if on-farm storage is to take place;
- clean trucks/wagons/augers prior to transporting IP crops;
- deliver the IP production to the co-operative at harvest.

b) Elevator level

The elevator is required to comply with the following IP requirements:

- use separate and dedicated storage silos;
- ensure that there is no co-mingling during unloading;
- deliver the IP production to the designated processor or export terminal specified in the contract.

c) Premium

The premium paid to elevators is $20 per tonne (17% of the farm level price of commodity-type maize based on the 1997 average of $114/tonne). Given a yield of approximately 10 tonnes per hectare, this equates to a $200 per hectare premium. This premium is shared between the elevator, the co-operatives and the farmer. Approximately 40% of this premium is considered to compensate for lower yields and the rest covers field isolation requirements, extra transportation costs and the extra IP costs incurred by the elevator. The part of the premium that reaches the farmer varies between co-operatives. In some cases 100% is returned to the farmer, while in other cases the co-operative retains some proportion.

Example 3: Objective: Waxy maize grown in Europe

Key features of the process and costs of maintaining IP for waxy maize are detailed below:

a) Farm level

- isolation in the field is mandated in the contract to avoid cross-pollination;
- separate storage facilities should be used. These may have to be purpose built and will therefore incur a capital cost;
- a premium of approximately $170/ha is paid to the farmer as compensation for the isolation restriction imposed in the contract;
- the yield of waxy maize is currently 10-15% below that of commodity-type varieties and farmers need to be compensated for this shortfall. The compensation paid is broadly equivalent to the lost yield multiplied by the sale price of the maize (this will therefore be contract specific);
- additional costs associated with husbandry which usually requires additional use of crop extension advisors relative to non-waxy maize growing.

b) Transport

- separate storage is required during transport and this adds an additional 2-5% to the price of the maize ($3.60-9.00/tonne);
- a small extra cost is also incurred through testing to provide a guarantee that the maize is waxy. No cost for testing was provided to the researchers;
- additional transport costs if smaller scale loads and transport types are required as compared to commodity traded maize resulting from loss of efficiency. Figures for this were not provided.

Example 4: objective: high oleic sunflower

The supply chain IP requirements in order to retain the integrity of the trait include the following.

a) Farm level

Farmers/growers are required to undertake (via contracts to supply) the following:

- plant the specified seed product as stipulated in the contract;
- clean planter boxes prior to planting;
- provide a field map detailing where the product has been planted;
- clean combine prior to harvest;
- clean storage bins if on-farm storage is to take place;
- clean trucks/wagons/augers prior to transporting IP crops;
- deliver the IP production to designated elevator or processor at harvest.

Currently US sunflower growers who have contracted to produce high oleic sunflower are paid premia over commodity based sunflower. These premia (which were not disclosed to the researchers) clearly compensate for the additional costs of the above IP requirements, but also take into consideration the fact that these new varieties containing value added traits produce lower yields than conventional sunflower varieties. In respect of the IP costs alone, however, the organisation involved in contracting with farmers to grow the value-added sunflower indicated that the premia needed to cover this element of the additional costs was about 10 US dollars/tonne.

b) Elevator level

The elevator is required to comply with the following IP requirements:

- clean storage bins prior to the acceptance of the IP crop;
- ensure that there is no co-mingling during unloading or storage of these varieties with other sunflower;
- sample and test each load prior to unloading to ensure that quality specifications are met;
- deliver the IP production to the designated processor or export terminal specified in the contract.

IP costs at this level were not perceived to be significant relative to conventional sunflower. However, sunflower as a minority crop relative to say soyabeans has high costs of movement through this element of the distribution chain because economies of size in throughput cannot be realised.

c) Processor level

Sunflower crusher IP requirements include the following:

- ensure that storage tanks for products are clean prior to use;
- sample and test each load on arrival to ensure that quality specifications are met;
- ensure that there is no co-mingling during crushing. This can be done in one of two ways. Either the plant is thoroughly cleaned out between batches or some beans are run through the machinery and then discarded at the 'head' and 'tail' of each batch.

As with the elevator level, IP costs are not considered to be significant, except from the perspective referred to above relating to the volume processed of sunflower relative to say soyabeans.

d) Refiner level

No additional IP costs perceived, excepting the point referred to above concerning volumes of sunflower processed and economies of size.

A1.6. High laureate oilseed rape IP example

The supply chain IP requirements in order to maintain integrity of the trait at the farm level include the following:

- plant the specified seed product as stipulated in the contract;
- clean planter boxes prior to planting;
- do not plant high laureate varieties adjacent to other canola varieties or mustard fields to reduce the risk of cross-pollination;
- clean combine prior to harvest;
- clean storage bins if on-farm storage is to take place;
- clean on-farm transport equipment.

A premium of $15/tonne is provided as compensation for the above restrictions. In addition to this, the harvested canola is picked up free from the farm and, provided the harvested canola meets the laureate content specification, the cost of the seed is credited to the farmer. It is also possible for qualifying producers of these varieties to defer payment for inputs of up to $185/ hectare interest free until the end of October.

No information was available concerning the process or cost of maintaining high laureate integrity ex-farm.

A1.7. IP example for GM (herbicide resistant) oilseed rape

Use/context: IP implemented in the 1995 and 1996 production years to segregate herbicide resistant oilseed rape out of the commodity traded oilseed rape on world markets (ie, outside the US and Canada) – to avoid possibilities of co-mingling of GM oilseed rape with conventional oilseed rape destined for export to markets outside North America where regulatory approval for the GM technology in these oilseed rape varieties had, at that time, not yet been given. This was initiated and paid for by a combination of the technology suppliers (biotechnology companies), seed producers/suppliers and farmers themselves (the latter facilitated by farmers being members of marketing co-operatives). The GM oilseed rape was segregated from conventional oilseed rape and channelled to crushers in Canada and the USA only. The area sown to GM varieties was 121,000 hectares or 3% of the Canadian canola area in 1996. A larger programme is perceived to have probably required additional investment in infrastructure.

Production source: spring oilseed rape grown in Western Canada. The IP process and costs involved in this programme as applicable in 1996 were as follows (costs expressed as US dollars/tonne at the 1996 exchange rate of 1 US$=1.3635 Canadian):

- on-farm use of separate storage and handling: $0.73
- additional transport and storage costs of IP (separation, cleaning, transportation in smaller loads, not using the normal ‘elevator’ systems and by road transport rather than sea or rail: $6.60-$8.80. These costs were considered to have been minimised by the selection of farmers in close proximity to crushing facilities
- processor/crusher costs of IP (cleaning, separation): $2.20-$3.67
- administration, inspections, testing, monitoring: $3.67

This comes to a total additional cost of $13.20-$16.87 per tonne, equivalent to about 6-8% of the farm gate price for oilseed rape in 1996 ($205.35/tonne).

It should also be noted that at the time, prices of oilseed rape in North America tended to be about $7.33/tonne lower than prices that might have been obtained on world markets. Consequently, the decision to keep the GM crop out of export markets also resulted in the sellers foregoing the opportunity to sell in more profitable export markets outside North America.

Appendix 2: List of key relevant EU legislation

Regulation, Directive or decision	Subject
Dir 90/220	Deliberate release of GMOs into the environment.
Reg 258/97	Novel foods and ingredients.
Decision 96/281	Placing on the market of GM soyabeans with increased tolerance to the herbicide glyphosate.
Decision 97/98	Placing on the market of GM maize with the combined modification of insect resistance (Bt) and tolerance to the herbicide glufosinate ammonium.
Reg 1139/98	Labelling of certain foodstuffs produced from GMOs.
Dir 79/112	Approximation of laws relating to the labelling, presentation and advertising of foodstuffs.

Appendix 3: Costs of IP: the different stages

a) Pre-farm

- *Plant (seed) breeding*: The development of new crop varieties currently takes place under very controlled conditions. Distances of about 300 metres are maintained between crops to minimise chances of cross-pollination (aeolian or through bees) taking place. Although some crops are less likely than others to exhibit cross-pollination (eg, maize compared to oilseed rape), this 300 metre distance is enforced irrespectively of the crop varieties planted in trials. As a result the 300 metre *cordon sanitaire* is universally accepted as reasonable for maintaining purity levels at 99% (that is allowing a 1% tolerance level)[24]. Provided this level of purity and tolerance is considered as acceptable in respect of GM varieties, no changes to current practices would arise and no additional costs would be incurred.
- *Seed multiplication:* As with plant breeding, conventional systems of multiplication are closely monitored. Multiplication usually takes place with a 200-300 metre distance between crops (depending on the crop and the risk of cross-pollination). This *cordon sanitaire* is universally accepted as reasonable for maintaining purity levels at 98% (ie, a 2% tolerance level). Provided this level of purity and tolerance is considered as acceptable in respect of GM varieties, no changes to current practices would arise and no additional costs would be incurred.
- *Seed distribution*: Under conventional systems, different varieties are separately bagged and labelled. For GM varieties, no differences would be likely to occur and hence no extra costs are likely to occur.

b) Farm-level

IP requirements at the farm level can be considered in three stages, planting, harvest and storage.

i) Planting

- *Plant the specific seed product*. In order to enter produce into an IP chain, the farmer first has to ensure that the correct seed is planted. This means that different seed bags should not be mixed together. This should be fairly simple to do as seed is usually bagged and labelled according to contents and farmers are currently used to dealing with multiple varieties of particular crops and are unlikely to mix seed accidentally at this stage. Where the intention is to IP a crop for which distinct husbandry practices are required (eg, a herbicide tolerant GM crop), then clearly the result of mistakes at this stage would become apparent to the farmer after, for example, herbicide application. Additional care and double-checking is therefore likely to occur in such a case although the additional costs involved would be negligible.
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[24] It is impossible to ensure 100% purity unless production takes place within a hermetically sealed unit.

- *Clean planting equipment***.** In order to avoid co-mingling via a seed drill, these implements must be thoroughly cleaned before use. The amount of time spent cleaning would depend to some extent on the IP tolerance levels and if the IP tolerance level was extremely tight (eg, 0.01%), this might necessitate the use of separate machinery for each crop to be segregated.
- *Avoid cross-pollination***.** This depends to some degree on the ability of the crop to cross-pollinate with other, non-IP varieties. Research carried out on herbicide tolerant oilseed rape suggests that it is technically possible for cross-pollination to take place. However, the (already small) likelihood of cross-pollination diminishes as the distance between modified and non-modified crop increases (Scheffler, *et al*, 1993). To minimise the possibility of cross pollination careful siting of crops is likely to be required (ie, use of a *cordon sanitaire* between GM and non-GM crops). Production without a reasonable *cordon* (ie, growing a GM variety immediately adjacent to a non GM variety) could lead to purity levels as low as 70-75% (ie, a tolerance level of up to 30%). This is clearly unacceptable and farmers typically growing specific varieties (usually under contract to a processor) maintain a distance between varieties that they wish to IP and other crops of a similar nature.
- *Keep accurate records of plantings.* This is essential to avoid confusion after harvest and ensure IP. Whilst this will increase the time (and cost) involved for farmers it has become an increasing feature of farming in recent years, especially as quality assurance schemes requiring traceability have become more prominent. As indicated above, the extent to which this increases costs to the farmer will depend on the level of tolerances set. This issue is discussed further in the case studies of Part II.

ii) Harvest

- *Clean combine prior to harvest***.** This is essential in order to avoid inadvertently mixing other crops with those requiring IP. Tolerance levels will dictate the degree of cleaning to be required and the more restrictive the level of tolerance the greater the cleaning costs are likely to be. In addition to the cost of cleaning, there may also be an additional cost associated with a reduction in the timeliness for use of machinery (more time spent cleaning means less time harvesting, which increases costs). If tolerance levels were set at very low levels (eg, 0.001%) it might also be necessary to use separate machinery for IP crops, although in such a case, it is unlikely that a farmer would choose to grow IP and non-IP varieties of the same crop.

iii) Storage

- *Clean on-farm storage bins***.** Storage bins must be cleaned out (or new, dedicated facilities built if tolerance levels are set at very low levels) to ensure that the post-harvest mixing of crops could not take place. The degree of cleaning required (and hence the cost) would depend on the tolerance levels employed. In the event that IP and non-IP varieties are grown, careful management will be required to ensure that crops are not stored in the wrong storage bins or stored together.

c) Transport

- *Clean lorries/wagons/augers prior to transporting IP crops***.** Again, the costs incurred here will depend on the tolerance levels set. IP would require transport companies to keep careful records of which lorries and wagons had been used for which IP crop and variety. Given the range of other uses to which lorries and wagons may be put, this level of administration and control could be difficult to achieve and costly (in a sector which is widely recognised as operating on low margins). Additionally, the issue of liability for contamination during transit will have to be clarified and could restrict the number of operators prepared to transport IP produce.
- *Clean storage bins prior to accepting delivery of IP crops.* The amount of cleaning required (and thus the cost) will depend on the stipulated tolerance level. IP would require dedicated (and possibly purpose built) storage facilities.
- *Ensure there is no co-mingling during the loading or unloading process***.** This would require cleaning any equipment used in the loading/unloading process and would entail both a labour cost and a downtime cost (dead time for cleaning when machinery might otherwise have been in use). Very low levels of tolerance might necessitate dedicated loading/unloading equipment.
- *Sample and test each load***.** For GM crops containing quality traits, testing would be required to ensure that traits (eg, higher oil content) matched specifications (tolerances). For GM crops with agronomic traits the testing would be limited to DNA/protein tests to determine the presence (or absence) of GMOs. In both cases the cost of testing will depend on the level of tolerance (the lower the tolerance the more sophisticated the testing equipment and procedures are likely to be required).
- *Ensure correct delivery of the IP produce***.** There is the potential for mistakes to be made and produce to be delivered to the wrong processor, export terminal or user. However, this potential already exists for conventional crops and products and should not pose an insurmountable problem, but it may involve some small, additional management costs.

d) Further storage

Any additional storage requirements would lead to the same problems and associated costs discussed above in respect of on-farm storage.

e) Processing

- *Ensure storage tanks are clean prior to use***.** The degree (and cost) of cleanliness will depend on the level of tolerance. Very low tolerance levels would probably require dedicated storage facilities.

- *Sample and test each processing batch*. This might be necessary to ensure that the quality specifications (quality trait GM products) have been preserved or for agronomic traits that the required level of tolerance for presence of DNA or protein has been met. The costs here will depend on the level of tolerances set and the extent to which confidence exists in the IP previously undertaken to this point from the farm.
- *Clean the processing machinery*. This is required to ensure that co-mingling does not take place during processing. The extent and cost of cleaning required will depend on the tolerance levels used. In addition to the labour costs of cleaning, there would also be costs associated with shutting down processing lines, especially where continuous rather than batch processing systems are used. Very low levels of tolerance would probably require dedicated processing facilities.

f) Distribution

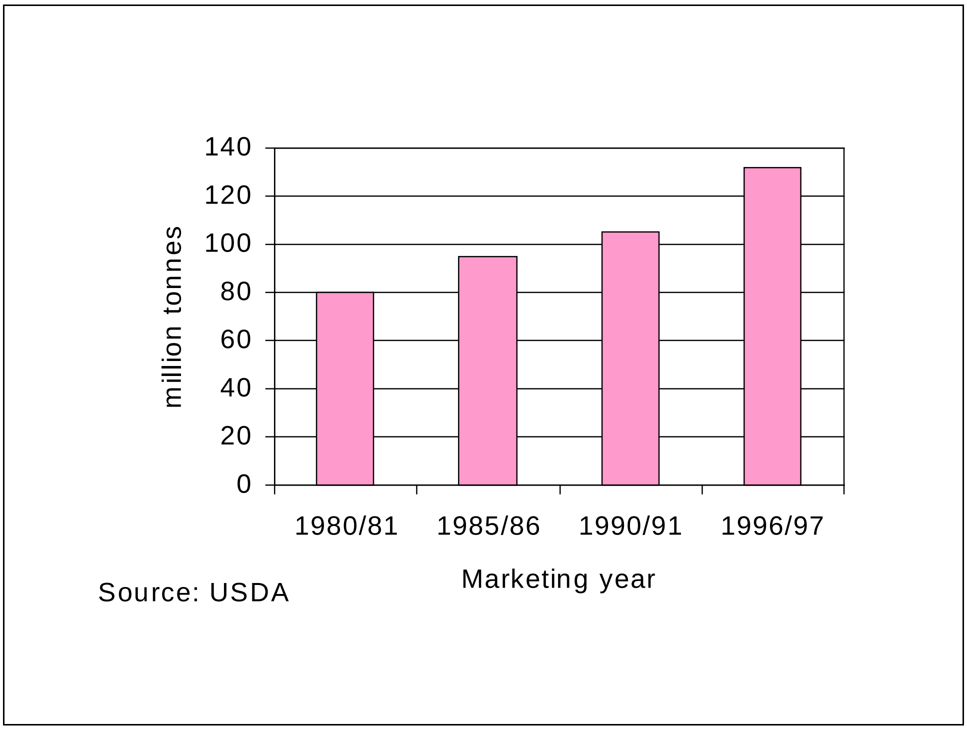
- *Ensure that IP products go to the correct end user*. This may necessitate use of separate storage and transportation to conventional products. Additional costs might also arise from a loss of economies of size in transportation (eg, the cost per tonne of transporting produce in a 50,000 tonne ship are significantly lower than the cost of perhaps shipping in a 5,000 tonne capacity ship). The magnitude of these latter costs will however depend on the size of the market for the IP product relative to conventional product markets.

g) Labelling

- *Ensure correct labelling*. Additional costs relating to labelling include:
  - additional time for checks and the associated cost of ensuring that IP products are separately and correctly labelled;
  - the capital cost of re-setting, re-designing and printing labels to meet the new requirements;
  - costs of policing the new requirements to ensure compliance and the avoidance of fraudulent labelling occurring (eg, of products purporting to GM-free which are not or products containing a GM quality trait that it does not possess).

Appendix 4: Further details about the markets, use and production of the case study crops

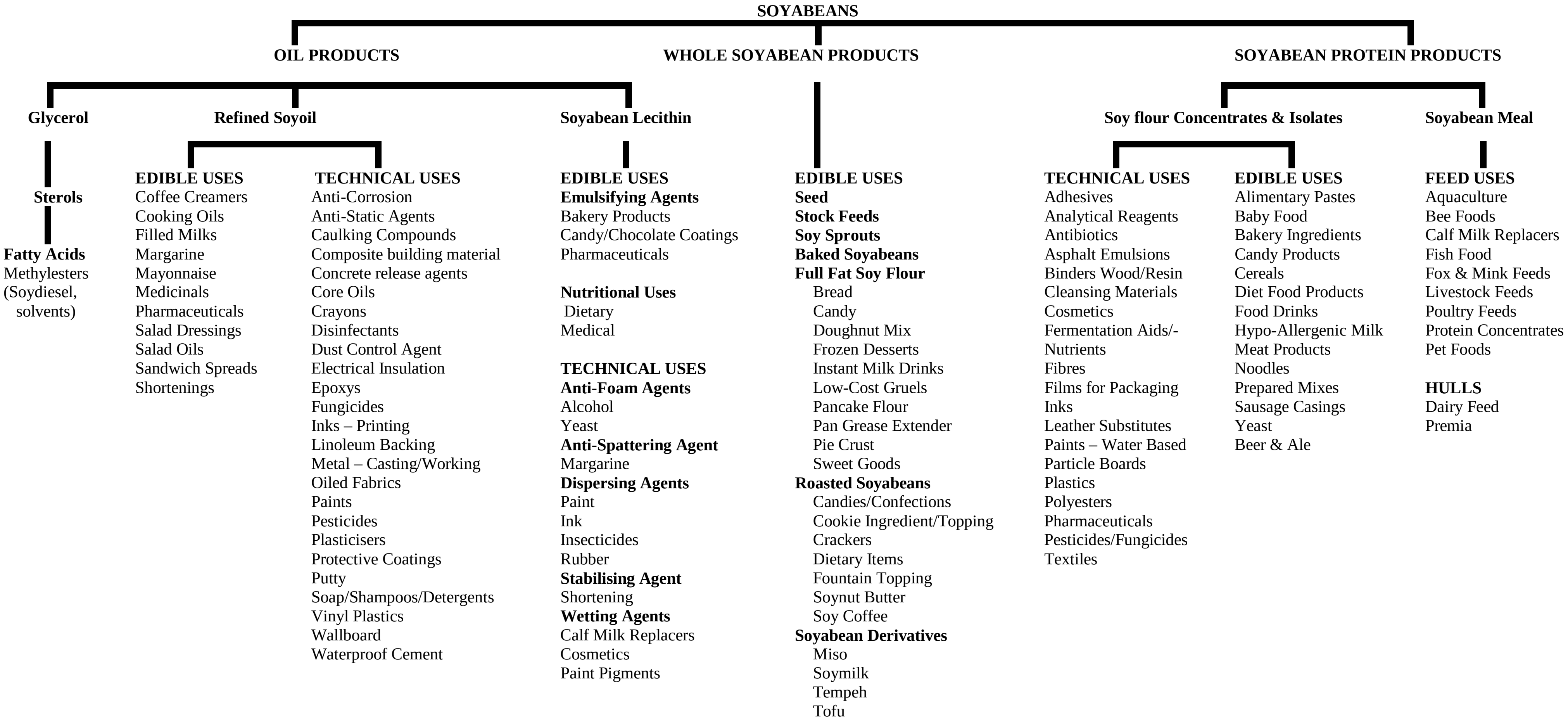
A: Soyabeans



Source: USDA

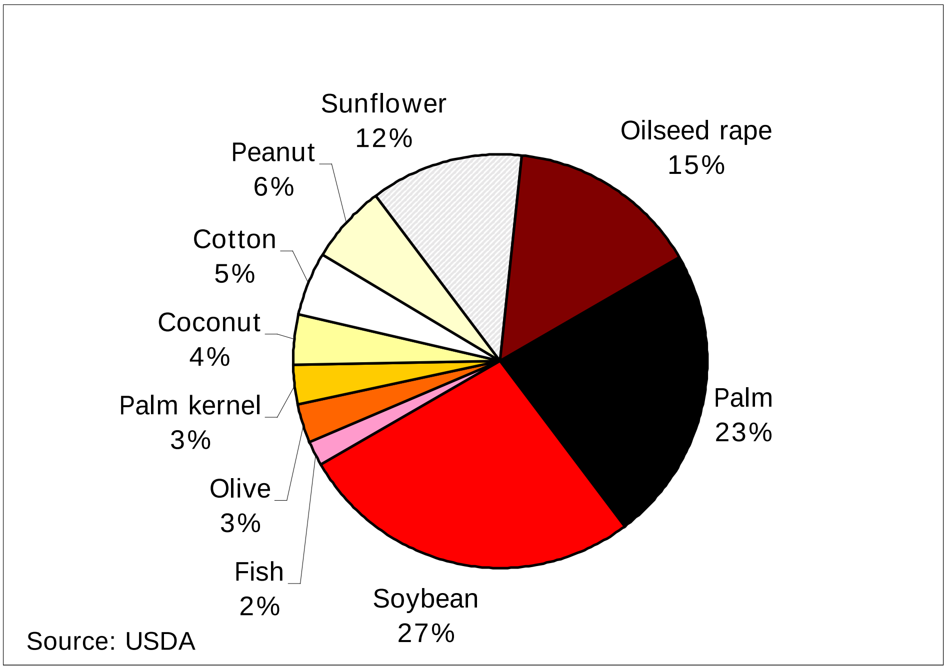
Figure A4.1: World soyabean use 1980/81-1996/97

Figure A4.2: Soyabean uses



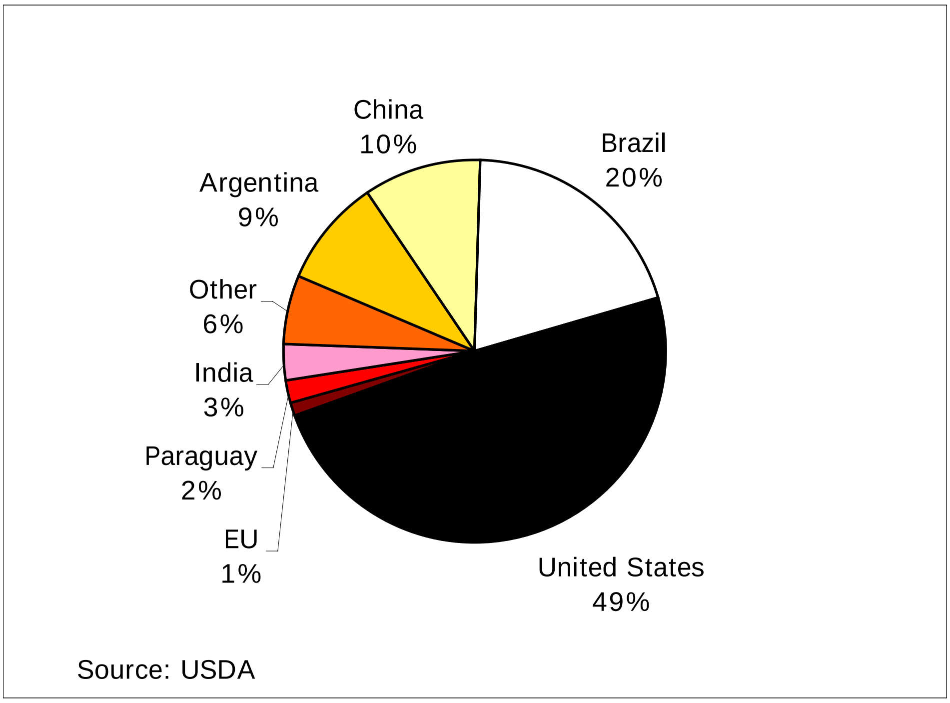
SOYABEANS

- **OIL PRODUCTS**
  - **Glycerol**
    - **Sterols**
      - **Fatty Acids**
        - Methylesters (Soydiesel, solvents)
  - **Refined Soyoil**
    - **EDIBLE USES**
      - Coffee Creamers
      - Cooking Oils
      - Filled Milks
      - Margarine
      - Mayonnaise
      - Medicinals
      - Pharmaceuticals
      - Salad Dressings
      - Salad Oils
      - Sandwich Spreads
      - Shortenings
    - **TECHNICAL USES**
      - Anti-Corrosion
      - Anti-Static Agents
      - Caulking Compounds
      - Composite building material
      - Concrete release agents
      - Core Oils
      - Crayons
      - Disinfectants
      - Dust Control Agent
      - Electrical Insulation
      - Epoxys
      - Fungicides
      - Inks – Printing
      - Linoleum Backing
      - Metal – Casting/Working
      - Oiled Fabrics
      - Paints
      - Pesticides
      - Plasticisers
      - Protective Coatings
      - Putty
      - Soap/Shampoos/Detergents
      - Vinyl Plastics
      - Wallboard
      - Waterproof Cement
  - **Soyabean Lecithin**
    - **EDIBLE USES**
      - **Emulsifying Agents**
        - Bakery Products
        - Candy/Chocolate Coatings
        - Pharmaceuticals
      - **Nutritional Uses**
        - Dietary
        - Medical
    - **TECHNICAL USES**
      - **Anti-Foam Agents**
        - Alcohol
        - Yeast
      - **Anti-Spattering Agent**
        - Margarine
      - **Dispersing Agents**
        - Paint
        - Ink
        - Insecticides
        - Rubber
      - **Stabilising Agent**
        - Shortening
      - **Wetting Agents**
        - Calf Milk Replacers
        - Cosmetics
        - Paint Pigments
- **WHOLE SOYABEAN PRODUCTS**
  - **EDIBLE USES**
    - **Seed**
    - **Stock Feeds**
    - **Soy Sprouts**
    - **Baked Soyabeans**
    - **Full Fat Soy Flour**
      - Bread
      - Candy
      - Doughnut Mix
      - Frozen Desserts
      - Instant Milk Drinks
      - Low-Cost Gruels
      - Pancake Flour
      - Pan Grease Extender
      - Pie Crust
      - Sweet Goods
    - **Roasted Soyabeans**
      - Candies/Confections
      - Cookie Ingredient/Topping
      - Crackers
      - Dietary Items
      - Fountain Topping
      - Soynut Butter
      - Soy Coffee
    - **Soyabean Derivatives**
      - Miso
      - Soymilk
      - Tempeh
      - Tofu
- **SOYABEAN PROTEIN PRODUCTS**
  - **Soy flour Concentrates & Isolates**
    - **TECHNICAL USES**
      - Adhesives
      - Analytical Reagents
      - Antibiotics
      - Asphalt Emulsions
      - Binders Wood/Resin
      - Cleansing Materials
      - Cosmetics
      - Fermentation Aids/-Nutrients
      - Fibres
      - Films for Packaging
      - Inks
      - Leather Substitutes
      - Paints – Water Based
      - Particle Boards
      - Plastics
      - Polyesters
      - Pharmaceuticals
      - Pesticides/Fungicides
      - Textiles
    - **EDIBLE USES**
      - Alimentary Pastes
      - Baby Food
      - Bakery Ingredients
      - Candy Products
      - Cereals
      - Diet Food Products
      - Food Drinks
      - Hypo-Allergenic Milk
      - Meat Products
      - Noodles
      - Prepared Mixes
      - Sausage Casings
      - Yeast
      - Beer & Ale
  - **Soyabean Meal**
    - **FEED USES**
      - Aquaculture
      - Bee Foods
      - Calf Milk Replacers
      - Fish Food
      - Fox & Mink Feeds
      - Livestock Feeds
      - Poultry Feeds
      - Protein Concentrates
      - Pet Foods
    - **HULLS**
      - Dairy Feed
      - Premia



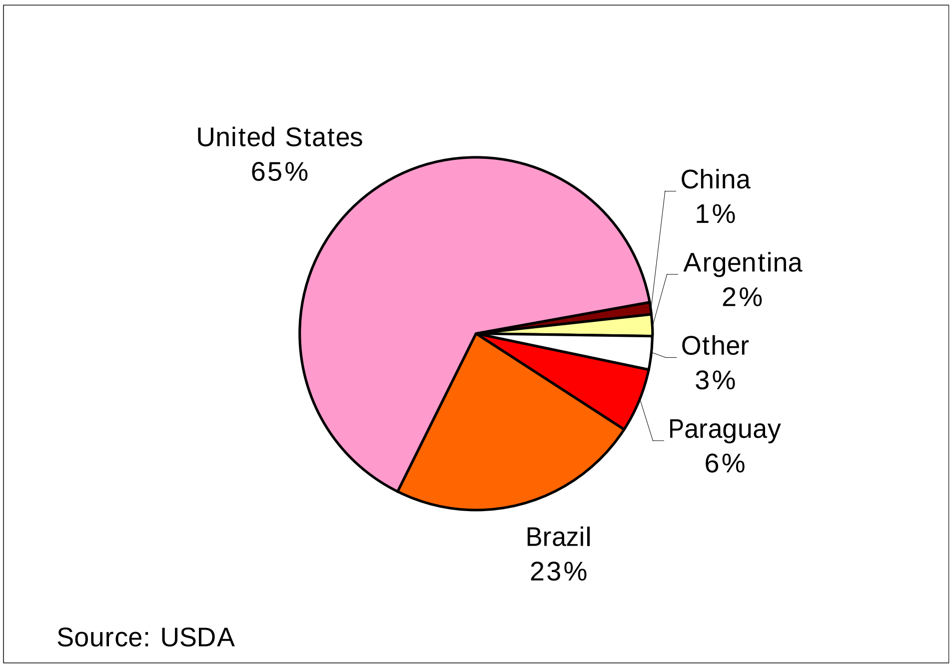
Source: USDA

Figure A4.3: World vegetable and marine oil consumption (1996/97)



Source: USDA

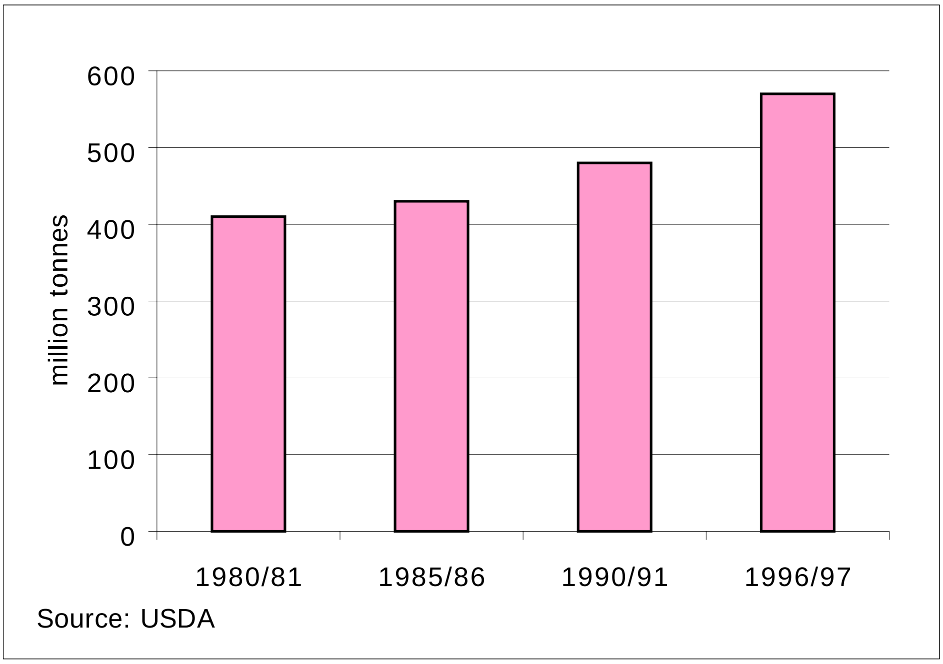
Figure A4.4: World soyabean production (1996/97)



Source: USDA

Figure A4.5: World soyabean trade (1996/97)

B: Maize



Source: USDA

Figure A4.6: World maize use and trade (1980/81-1995/96)

Figure A4.7: Uses of maize

MAIZE USES

FOOD APPLICATIONS

Baking
Fermentation:
Bread, Buns, Rolls
Sweet Yeast Goods (Danish, Doughnuts, etc)

Non-fermentation:
Cakes (layer, snack) Cake Doughnuts
Cookies
Creamed Fillings
Icings and Glazes
Pie, Doughnut Fillings
Prepared Mixes
Beverages
Beverage Powders
Beer (Light & Regular)
Soft Drinks (Carbonated & Non-carbonated)
Wine & Liqueurs
Canned Products
Fruits & Juices
Puddings & Miscellaneous
Vegetables
Confectionery
Caramel
Chewing Gum
Hard Candy
Marshmallow, Nougat & Seafoam
Pan Coatings
Tableting
Processed Foods
Condiments
Dairy Products
Food Powders
Frozen Foods
Jams, Jellies, Preserves
Meat Products
Pickles
Syrup Blending
Vinegar

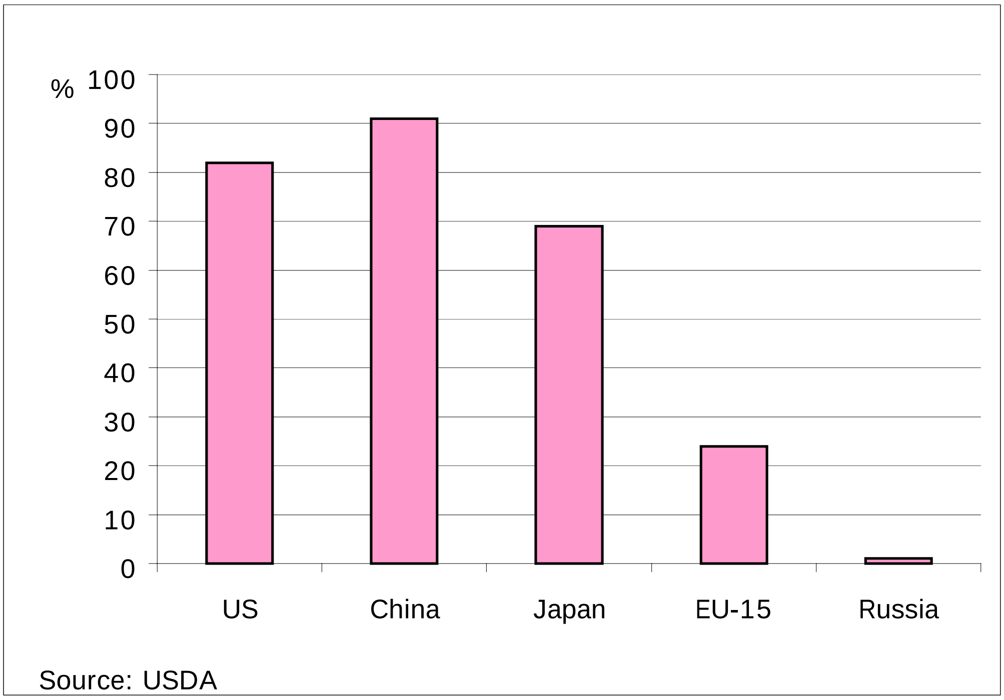
INDUSTRIAL APPLICATIONS

Adhesives
Bag Adhesives
Envelope Adhesives (Back Gum)
Library Paste
Laminating Adhesives
Building Materials
Wallboard
Acoustical Tile
Concrete Additives
Plaster
Chemicals
Sorbitol Manufacture
Resin Manufacture
Cluconic Acid, Gluconates & Gluco-heptonates
Chemicals
Floral Chemicals
Enzyme Manufacture
Rodenticides, Insecticides, Herbicides
Air Fresheners
Metal Treatment
Industrial Compounds & Powders
Dye Manufacture
Emulsion Polymerisation (PVAc)
Corrugating
Adhesive System
Cosmetics
Dusting Powder, Face Powder (Powdered & Caked), Eye Shadow (Powdered & Caked)
Liquid Colognes, Perfumes
Fermentation
Fermentation
Mining
Iron Ore
Bauxite Aluminium
Beneficiation
Fluorspar Beneficiation

Paper Converting
Remoistenable Adhesives
Bag Adhesive
Paper Manufacturing
Wet End
Surface Sizing
Calender Sizing
Coating
Pharmaceuticals
Medicinal Syrups
Intravenous Solutions
Vitamin "C" Manufacture
Tableting
Lozenges
Dosage Forms
Fermentation
Textiles
Weaving (Cotton)
Finishing
Tobacco
Tobacco Additive
Cigarette Seam & Plug Adhesive

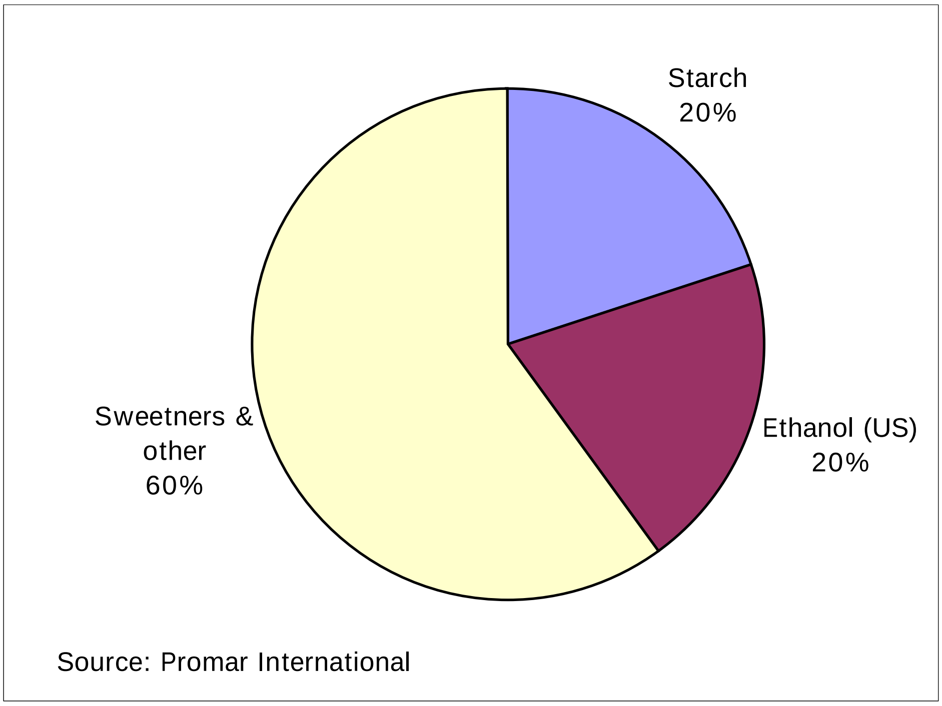
FEED APPLICATIONS

Layer, Swine, Turkey,
Dairy, Beef
Feeds, Pet Foods
Carrier, Beef, Dairy Feeds
Broiler Feeds, Fish Foods
Liquid Feeds, Range Blocks, Feed Flavour
Baby Pig Feeds, Milk Replacers



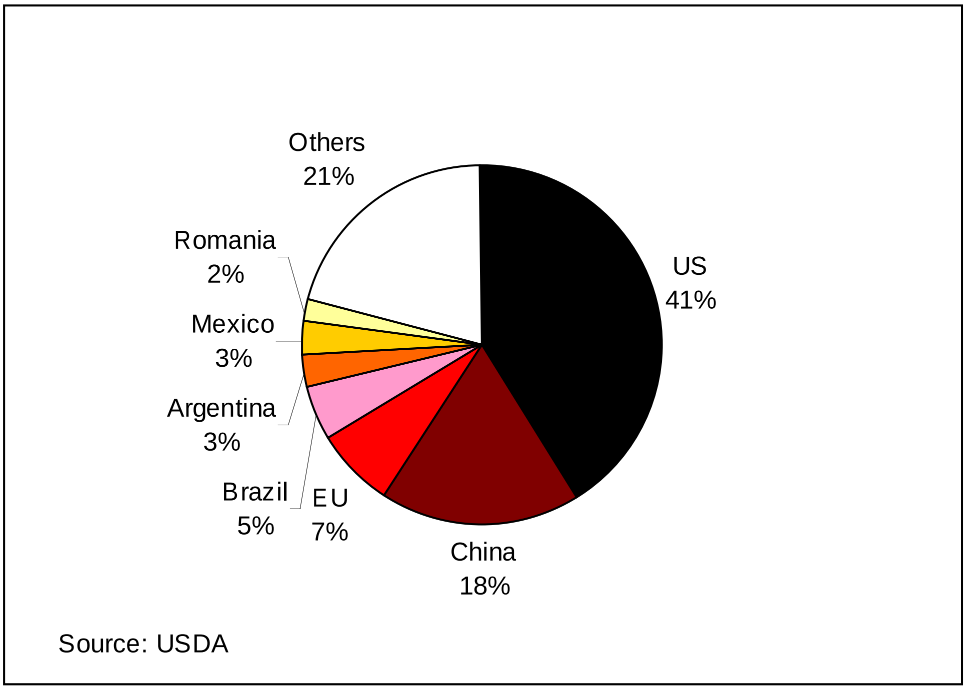
Source: USDA

Figure A4.8: Maize share of grain used in animal feed (1996/97)



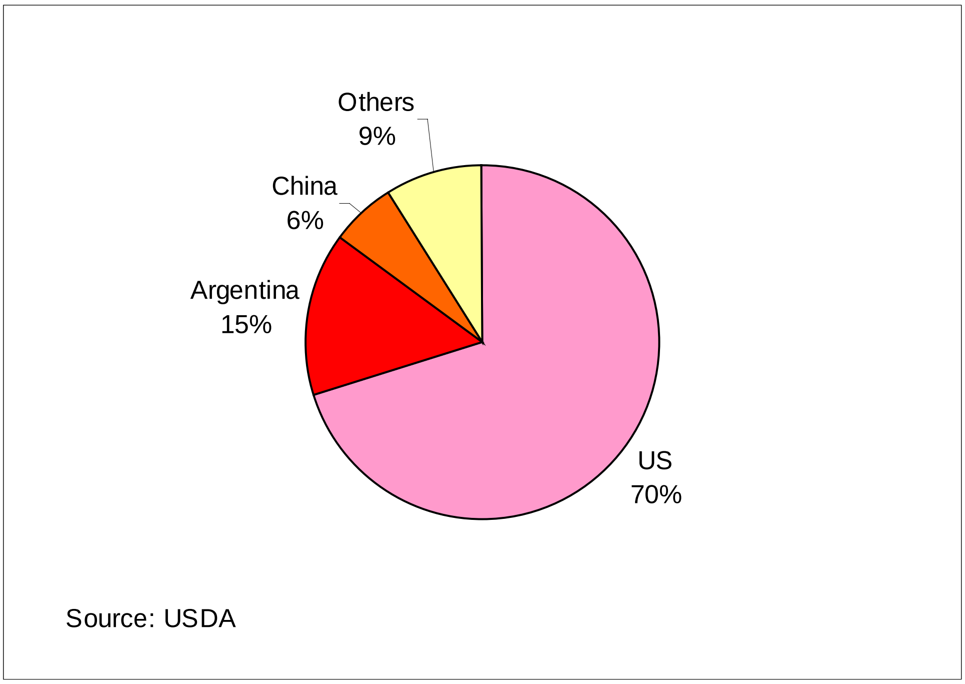
Source: Promar International

Figure A4.9: Distribution of global industrial uses of maize, 1996



Source: USDA

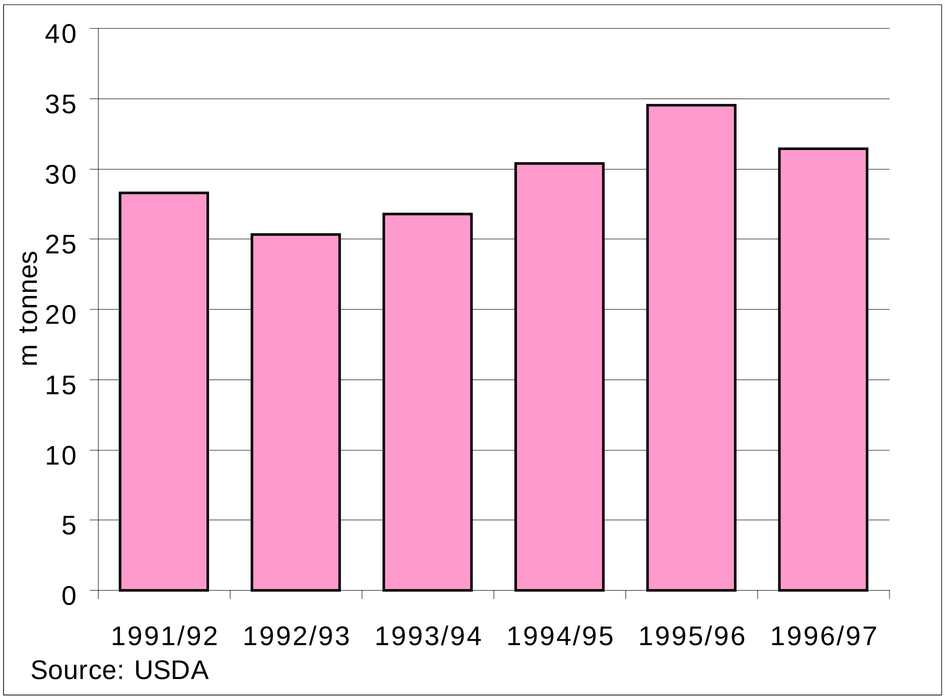
Figure A4.10: World maize production 1996/97



Source: USDA

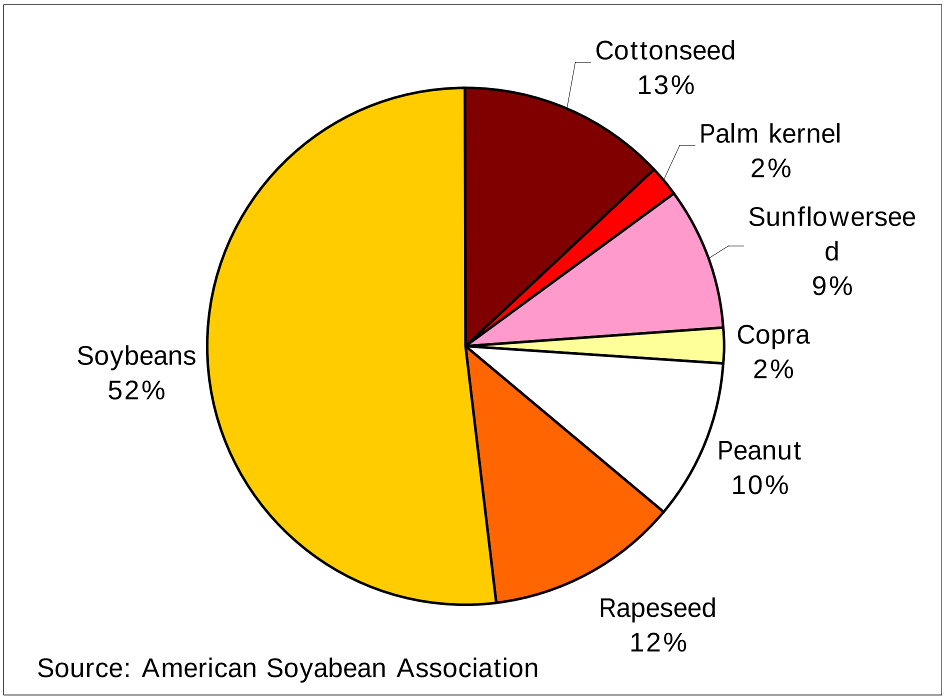
Figure A4.11: World maize trade 1996/97

C: Oilseed rape



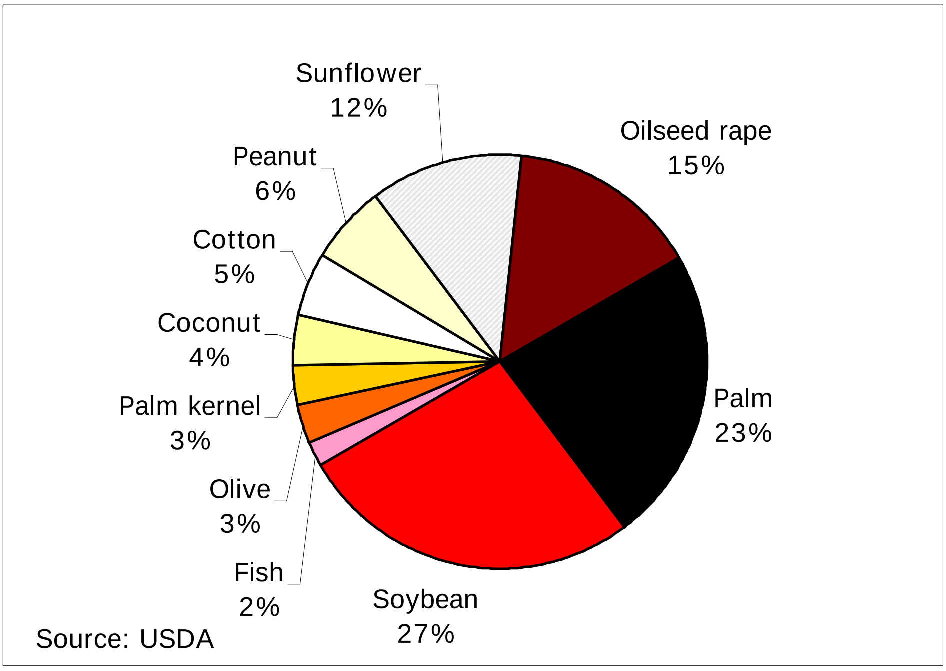
Source: USDA

Figure A4.12: World production of rapeseed



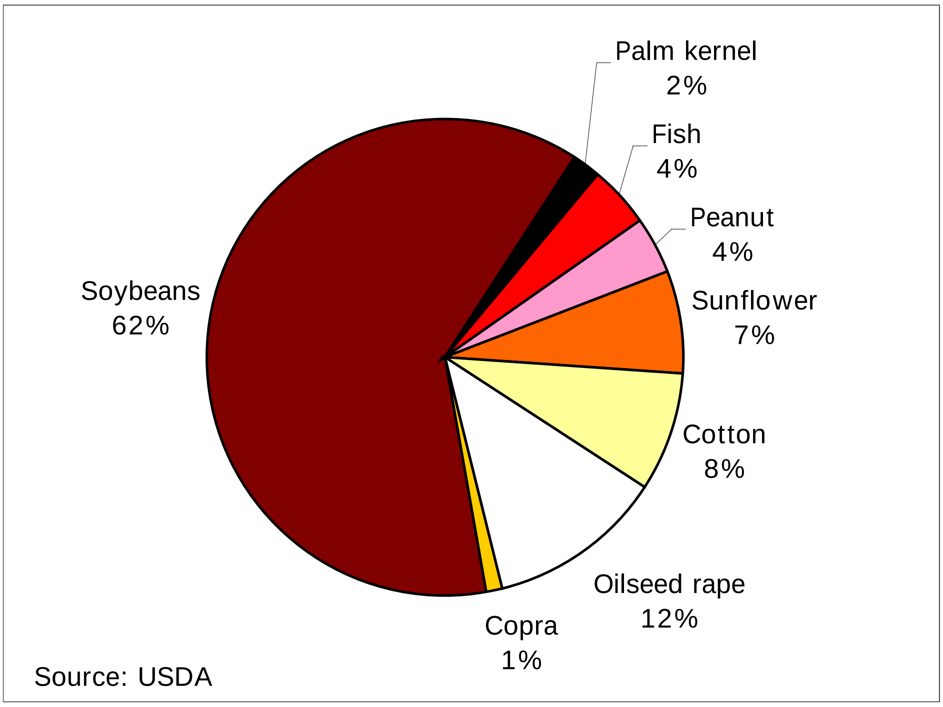
Source: American Soyabean Association

Figure A4.13: World oilseed production 1996



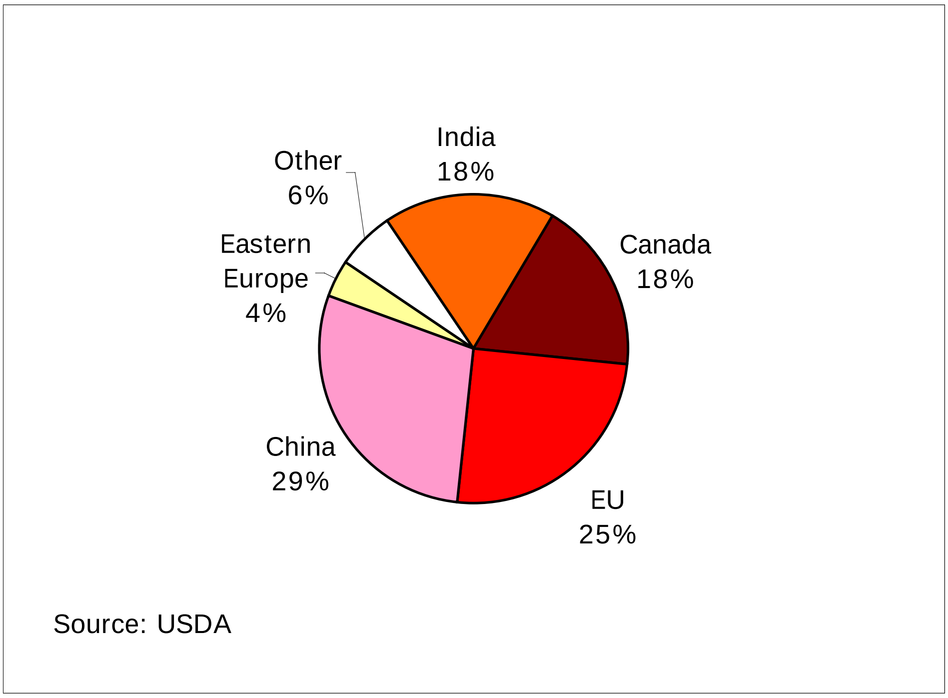
Source: USDA

Figure A4.14: World vegetable and marine oil consumption



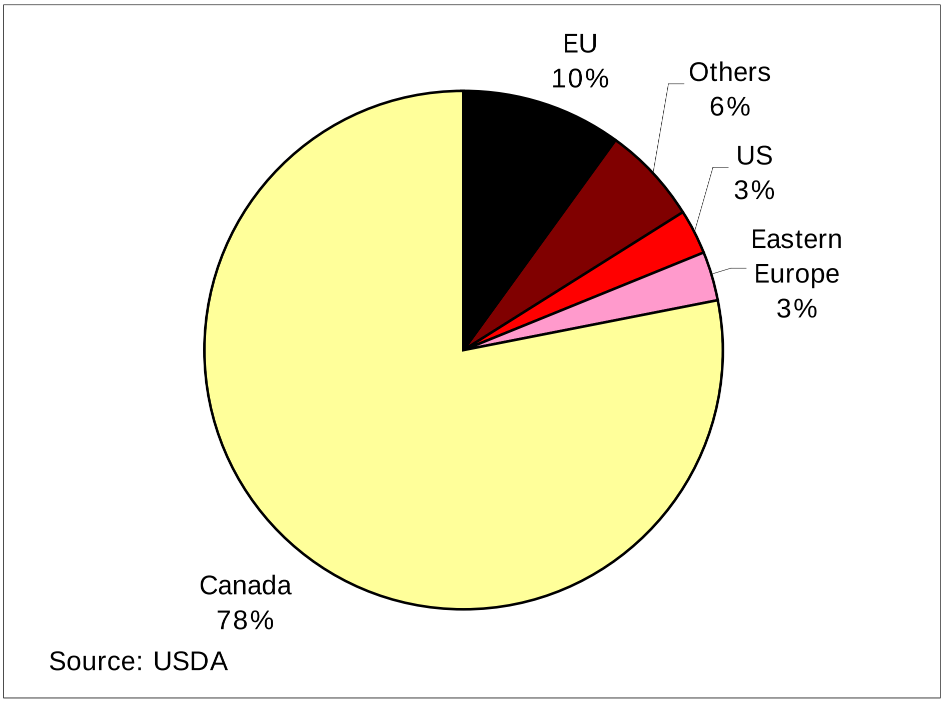
Source: USDA

Figure A4.15: World protein meal consumption



Source: USDA

Figure 4.16: Oilseed rape world production



Source: USDA

Figure A4.17: World rapeseed trade

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