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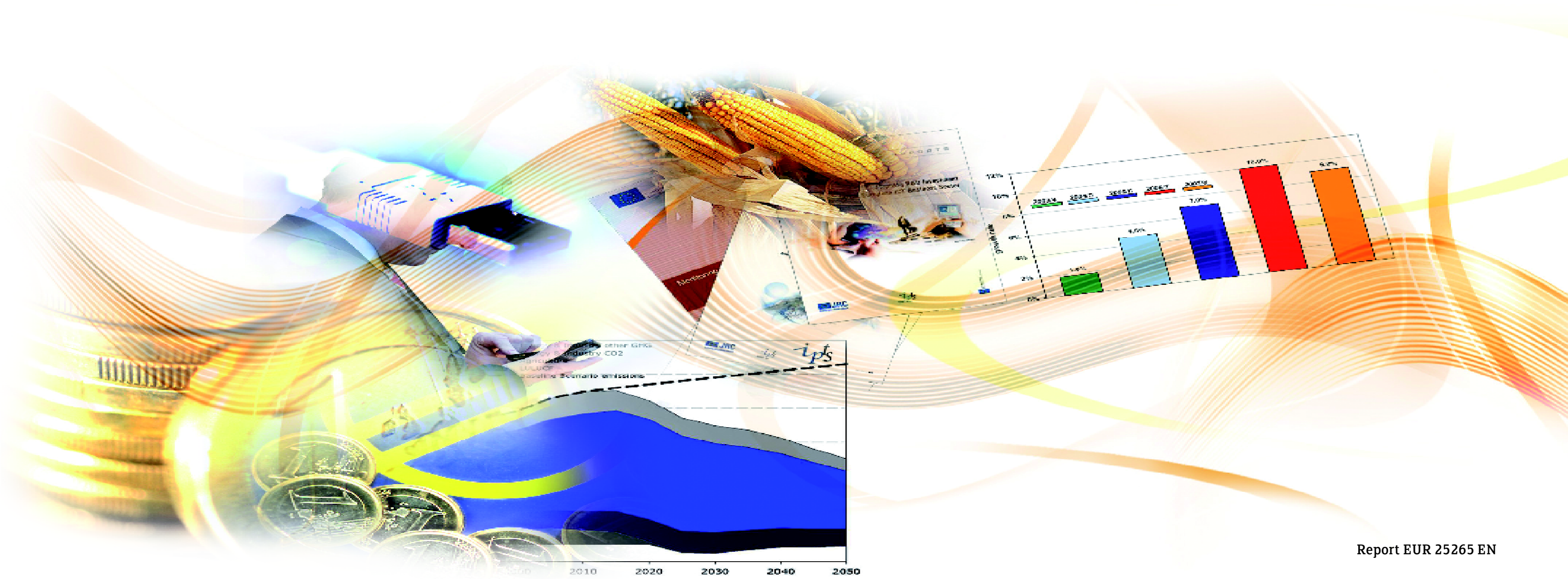
International workshop on socio-economic impacts of genetically modified crops co-organised by JRC-IPTS and FAO

Workshop proceedings

Maria Lusser, Terri Raney, Pascal Tillie,
Koen Dillen and Emilio Rodríguez Cerezo

2012



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Abbreviations

Bt	*Bacillus thuringiensis*
CBD	Convention on Biological Diversity
CGIAR	Consultative Group on International Agricultural Research
CPB	Cartagena Protocol on Biosafety
Cry	Crystal
CRW	Corn Rootworm
DALY	Disability Adjusted Life Years
DG SANCO	Directorate General for Health and Consumers
DNA	Deoxyribonucleic Acid
EC	European Commission
EFSA	European Food Safety Authority
EP	European Parliament
EU	European Union
EUR	Euro
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gas
GM	Genetically Modified
GMO	Genetically Modified Organism
HCB	High Council of Biotechnology
HT	Herbicide Tolerance
IPTS	Institute for Prospective Technological Studies
IR	Insect Resistance
JRC	Joint Research Centre
MS	Member State
RNA	Ribonucleic Acid
SEA	Socio-Economic Assessment
UK	United Kingdom
UN	United Nations
USA	United States of America
WTP	Willingness To Pay

Executive Summary

Background

- The EU GMO (genetically modified organisms) legislation provides for monitoring (*ex post* assessment) and reporting on the socio-economic implications of the deliberate release and placing on the market of GMOs.

- At the request of the Environment Council in December 2008, the Commission gathered available data from the Member States on the socio-economic implications of the cultivation of GMOs and published a report in 2011. In view of the quantitative and qualitative heterogeneity of the information provided, the Commission recommended in the report that, in order to gain a better understanding of these impacts in the specific EU context, a methodological framework should be built up to define the precise socio-economic indicators to be monitored and to establish appropriate rules for data collection.

The Workshop

- The Institute for Prospective Technological Research (IPTS) of the Commission's Joint Research Centre (JRC) was requested to review for policy makers the main findings of scientists who are active worldwide in the field of socio-economic assessment (SEA). In order to fulfil this task, an "International workshop on socio-economic impacts of genetically modified crops" was co-organised by the JRC-IPTS and FAO (Food and Agriculture Organization of the United Nations) in November 2011.

- The workshop brought together leading experts in the field to present their research results to experts from the Member States and to discuss experiences and the further development of SEA. The coverage of the workshop was worldwide and structured into seven sessions ranging from farm level to consumer impacts.

The Socio-Economic Impacts on Farmers

- Large-scale planting of GM crops started in 1996. In 2010 148 million hectares (10% of the world cropped area) in 29 countries were already covered by GM crops, half of them grown in developed countries and the other half in developing countries. However, the diversity of GM plants is still very low in terms of the crops and traits accessible to farmers. Four crops represent virtually the whole biotech area.

- ***The herbicide tolerant (HT) soybean*** (covering 50% of the world's GM area) has been very quickly adopted in those countries where it is available to farmers (100% of soy in Argentina is GM and 93% in the USA). In both countries, adoption had small and generally insignificant yield effects. Incremental profits for farmers are small, but larger in South America than in North America, reflecting differences in Intellectual Property Rights schemes.

- In both regions the extremely fast adoption rate is generally associated with the significant ease of use, efficiency, and flexibility that HT soybeans confer for weed control. In Argentina, HT soybeans also enable double cropping i.e. soybeans planted as a second crop after wheat. As for the USA, a recent study conducted in the Midwest shows that the adoption of GM soybeans tends to reduce the rate of use of all types of variable inputs (capital, labour, energy, chemicals and other materials) and generates in the mid-term a benefit-cost ratio of about 3.6.

- ***Insect Resistant (Bt) maize*** (31% of the global GM area) is cultivated in the highest number of countries (16; six of which are in the EU). In the USA, the adoption of GM maize has reached 86% of the total maize area (when considering Bt maize, HT maize and stacks together). In this country, cultivation of GM crops is associated with a small but significant increase in yield and with a reduction in the use of insecticides. In Midwestern US states, the output effects of the adoption of GM maize varieties are shown to be insignificant but the rate of use of all input groups (capital, labour, energy, chemicals and other materials) tended to decline, leading to a benefit-cost ratio of roughly 5.2.

- Bt maize is the only GM crop grown in the EU in significant amounts (mainly in Spain). Detailed surveys in Spain report gains for farmers of +195 EUR/ha/year mainly due to the increase in yield and reduced insecticide use.

- ***Bt cotton*** is the most studied GM crop in socio-economic terms. India is the first country in the world in terms of area of Bt cotton, followed by China and by the USA. In India, it amounts to 90% of the total cotton area, and growers are mainly smallholders. Bt cotton strongly reduces insecticide use and increases yields, as farmers were not entirely efficient at controlling pests before the adoption of GM cotton. The positive effects of Bt cotton cultivation have also been observed in many other countries worldwide, and related literature is abundant. The benefits in tropical countries are greater than in temperate countries because of the higher pest pressure.

- The ***sustainability of the benefits over time*** will depend on the adoption of "best agricultural practices", either for conventional or GM crops, in particular to prevent the advent of any kind of resistance on weed or pests that will make technology fail. The issue of environmental impacts of GM crops and how to introduce externalities into economic analyses is under debate.

- A number of ***methodological issues*** are associated with the impact assessment of GM crops at farm level, especially in developing countries where researchers must collect data in personal interviews with farmers due to the lack of reliable sources and where random sampling may not be feasible. During the first decade of published studies, the most commonly applied methodologies were partial budgets and econometric models of farm production, in which researchers tested hypotheses related to the yield advantages, labour and pesticide savings associated with adoption.

- Data quality was a major limitation of early studies, where samples were typically small, field observation periods were brief, and estimates of key parameters were often based on farmers' recall. Perhaps the most critical concern has been self-selection bias, i.e. the fact that farmers adopting the GM technology may also be the most efficient, or those with greater endowments and better access to markets or information. Additionally, the decision to grow a GM crop may be endogenous, and explained by other factors which are unobservable or not integrated into the model (like the pest pressure for instance). These methodological issues can be addressed by using advanced econometrical techniques.

Global Economic Impacts of GM Crops

- The cultivation of GM crops in a global market has effects upstream and downstream of the farming sector. GM seed suppliers profit by selling seeds, while users of the GM products (feed/food industry, the biofuel sector and textile industry) benefit from less expensive and/or better quality of raw materials. Consumers gain from lower commodity prices and sometimes increased quality attributes. As for the potential losers, manufactures of competitive inputs (insecticides, agrochemicals) lose market share and non-adopting farmers have a competitive disadvantage.

- Economic models have been developed to estimate the global economic welfare creation of GM cultivation and the distribution of its benefits among stakeholders. The data presented in the workshop show that HT soybeans generate 3 billion USD per year, distributed between the consumers/processors (50%), the adopting farmers (28%) and the innovating biotechnology sector (22%).

- Yet examples of economic research on welfare distribution are not many. Evidence suggests that institutional factors influence this distribution. Case studies covering different GM crops and countries indicate that the biotechnology sector captures 30% to 60% of the created benefits in developed countries. In countries with a lower degree of patent protection however, farmers capture 80%-90% of the benefits. Farmers in developing countries may experience a multiplicative effect on benefits: a farmer adopting GM crops expects higher yields and will therefore be attracted to buy underused inputs such as fertilizers, eventually resulting in even higher yield benefits.

- Spill-over of yield benefits and cost reductions are also important in the global markets as they influence prices, even for countries not cultivating GM crops but importing them. Models estimate that world food price increases would be significantly higher in the absence of GM cultivation, by 10% to 30% depending on the crop and the underlying assumptions. This price effect benefits all consumers globally through trade.

- In recent years a geographic shift of farmers' benefits was observed from the initial situation where benefits were concentrated in the USA, Canada and Argentina to a situation where small farmers in a variety of developing countries are obtaining more benefits from the technology. As a secondary effect, a shift in R&D investment in biotechnology to developing countries has been observed recently. Multinationals are opening research centres in countries where the crops will be grown. The creation of technology-related jobs has important multiplier effects on the local economies.

- The shift in benefits from the agro-chemical industry and conventional seed producers to the biotechnology industry also translates to a shift in R&D between these sectors. It is not clear whether this shift leads to a concentration in the agricultural input sector as the traditional players have activities in both conventional and GM markets.

Economics of Segregation/Coexistence of GM and non-GM Supply Chain

- The cultivation and marketing of GM crops is regulated in most countries and different public policies govern the segregation and coexistence between GM and conventional food and feed supply chains. In some countries market actors complement these regulations with private standards. For example, the EU-based food industry and retailers are hesitant to accept GM products and are willing to accept higher costs to avoid mandatory GM labelling while most of the EU feed industry accepts GM raw materials, relying solely on the legal thresholds for labelling.

- Segregation and coexistence policies result in additional costs but may also generate consumer benefits (consumer choice, creation of niche markets for non-GM labelled products etc). Until now, empirical studies mostly assessed the costs for farmers and their downstream supply chains in many parts of the world.

- At the ***farm level***, EU Member States apply coexistence policies for GM and non-GM farming, consisting of a set of *ex ante* regulations and *ex post* liabilities. So far, in all EU Member States' regulations, it is the GM farmer who should take the measures (usually administrative measures or technical measures such as isolation distances) and who bears the liability.

- The costs and feasibility of coexistence depend to a large extent on the threshold set for adventitious presence of GM crops in non-GM production. Beside the legal threshold for labelling (0.9%), some private operators in the EU (retailers or organic industry) demand higher private standards (0.1%). Farmers can minimize coexistence costs by cooperating and spatially aggregating the production of GM and non-GM crops (e.g. "Production zones" in Portugal).

- The general policy of European ***food industry and retailers*** to avoid GM raw materials can be achieved by sourcing ingredients from certified non-GM markets (at higher costs) and separating GM and non-GM ingredients in their processing facilities. Case studies show that the type and complexity of the supply chain to a great extent influence the segregation costs. The total additional costs of coexistence and product segregation systems can rise to almost 13% of production turnover for non-GM rapeseed oil while they represent only 0.6% in the case of a frozen pizza producer. These results show that the costs of coexistence and the feasibility in the supply chain should be considered on a case-by-case basis. Very little empirical information on these costs is available and often constitutes proprietary business data which makes it a challenging subject for research.

- The perceived demand of European consumers for non-GM food has created new niche markets for the food industry. In Germany, the government introduced a new "GM free" label and "GM free" logo (in 2008 and 2009) which has been managed by a stakeholder organisation since 2010. Since the launch of the GM free label there has been a steady growth in participants. Non-GM production incurs higher costs that have to be compensated in the market. Economic analyses showed that German farmers get a small price premium from the scheme to cover their extra costs (some 3-4% of the price for producers of milk from cows fed with non-GM feed).

- Food/feed ingredients are highly traded commodities and Europe is a top importer for maize, soybeans and soybean meal. To serve the non-GM grain markets worldwide (mainly Japan and the EU), grain traders use different types of spatial and temporal separation measures. However, some bottlenecks exist, e.g. the low number of ports used to ship the commodities from all over America or the production of certified seeds. Adventitious presence of non-approved GM crops in the non-GM supply chain did result in trade distortions and higher costs for European importers and processors. Indeed, the world prices for non-GM segregated grains have significantly increased in the past years.

Using Socio-Economic Studies in Decision Making for GM Crops Authorisation

- The ***2000 Cartagena Protocol on Biosafety (CPB)*** - part of the UN Convention of Biological Diversity – stipulates in Article 26.1 that for decisions on GMO imports, countries may consider SEAs of the impact of GMOs on the conservation and sustainable use of biodiversity, especially with regard to the value of biological diversity to indigenous and local communities. When implementing the PCB in the national legislation, many countries have gone beyond the contents of Article 26.1 by introducing other considerations, such as social, ethical or philosophical aspects.

- When a country includes a SEA in the GMO biosafety regulatory process it has to decide if the SEA should be voluntary or mandatory, if it should be carried out for approval (*ex ante*) and/or for post-release monitoring (*ex post*) and which methodology should be applied. For *ex ante* studies the choice of methods is limited and they necessarily will be based on projections and assumptions.

- As for potential implications of the introduction of SEAs in the regulatory process, SEAs will provide more and better information about the technological impact for the decision making process and may help to avoid the adoption of inefficient technologies. However, the regulatory compliance costs will increase, regulatory delays are possible and, if standards are not clear, the system might even become unworkable. The experts participating in the workshop argued that the inclusion of a robust SEA, in addition to strict science-based safety assessments, could make regulatory decision-making on cultivation more objective and transparent.

- Comparison of current approaches to the inclusion of SEAs in the GMO regulatory process in Argentina, Brazil and China shows significant differences. In Argentina, SEA is mandatory and comprises the *ex ante* assessment of economic impacts on trade and competitiveness. Brazil has introduced a non-mandatory SEA with an open scope and it is decided on a case-by-case basis if it is used. In China, the SEA is currently not included in the guidelines and regulations.

- Since the late 1990s, approvals of GM crops in Argentina have taken into account the state of play in other countries especially in the EU ("mirror policy") and also more recently in China and India. Decisions on the authorisation of cultivation of GM crops are made on the basis of three independent expert opinions: an environmental risk evaluation, a food and feed safety assessment and an analysis of the potential impacts on Argentina's international trade. The third expert analysis evaluates the stage of approval for production, consumption and import in the main importing countries and the competiveness of Argentina as an exporter for the crop, taking into account the situation of the import markets and other exporters.

Economic Compensation, Liability Issues and Institutional Framework Influencing Adoption of GM Crops

- Even with well-designed policies and regulations, unwanted harmful consequences of GMO cultivation can affect others' assets (e.g. through adventitious admixture in the agricultural supply chain) and, in order to compensate the victims, liability problems have to be solved. There are different mechanisms in place to deal with liability issues, regulation (liability/tort law) and market place liability.

- In ***Europe***, regulation is the common approach with tort law being a cornerstone. However, in spite of common fundamental values, tort law requirements vary substantially throughout Europe, leading to variations in the way potential claims would be handled and resolved. Moreover, tort law overlaps with other regulations such as good agricultural practice, coexistence rules and national policies.

- Insurance schemes can be introduced, in order to distribute the burden of liability for farmers cultivating GM crops between those contributing through the payment of premiums. Compensation funds established with contributions from farmers cultivating GMO crops and/or from government revenue could substitute where insurance schemes are absent. Indeed, compensation funds do exist in Denmark and Portugal, the latter being private and the former government-supported. All these schemes are theoretical and their actual applicability is unknown since there is no record of practical experiences or court cases in Europe.

- In the ***USA*** and ***Canada***, coexistence or segregation of GM crops and non-GM crops is not specifically regulated. Therefore, civil liability applies in the context of GM crop cultivation and liability issues are solved between private parties (marketplace liability). In the event of admixture, the product development company may be held responsible and obliged to pay compensation.

- Two cases from the USA illustrate situations where traces of unapproved GMOs were found in non-GM products. StarLink maize was detected in food products despite only being approved for feed use and, in the ensuing court case, plaintiffs who could prove that their crop, product or market had been negatively impacted by StarLink maize joined a class action lawsuit. In the other case, traces of LL601 rice (which was not yet authorised for marketing in the USA or in Europe) were found in US exports to the EU. The US rice industry lost the EU market for years after this incident and the biotechnology company recently offered USD 750 million in compensation to concerned rice producers.

- Institutional and political factors influencing the adoption and profitability of GM crops were discussed on the basis of studies from South Africa. The South African Government views biotechnology as a strategic industry to support economic growth and created an environment facilitating science-based and balanced considerations and regulation of GM crop cultivation which led to fast adoption of GM crop cultivation. The Makhathini Flats Bt cotton experience illustrates the importance of institutional factors in the adoption of GM crops by smallholder farmers. After the swift adoption of Bt cotton cultivation under favourable institutional conditions (institutional arrangement with one geographically isolated cotton gin supplying credit and extension services to contract farmers), the cotton cultivation system collapsed after institutional failure exacerbated by droughts and floods.

Consumers' Attitudes and Direct/Indirect Impacts on Consumers

- Many researchers have set out studies to measure the preference of consumers regarding GM or non-GM food products (estimated by the ***Willingness To Pay - WTP***). Two main types of methodologies to elicit consumers' valuation of non-GM products can be distinguished: stated or revealed preference. In the case of the first method, consumers' WTP is elicited in a hypothetical framework, for instance with questions about purchase intentions. This method is generally easier to implement, as it allows quick collection of data at low cost (which is specifically relevant in developing countries), although it usually leads to overvaluation of WTP ("hypothetical bias"). The second method, namely "revealed preference" elicits WTP for non-GM products by positioning consumers in real purchasing situations. Experimental auctions are especially useful in situations where no market for the assessed GM food products exists.

- A recent meta-analysis of studies confirmed the common assumption that consumers in developed countries have a preference for non-GM food, especially in Europe. A second assumption, namely that consumers in developing countries are more inclined to buy GM food than in industrial countries was questioned by experts who suggested that hypothetical bias (in these countries most studies rely on stated preference methods) may have led to an overvaluation of the preferences of consumers.

- A recent two-year study in the EU (ConsumerChoice, funded by EU Framework Programme for Research) evaluated consumers' WTP for non-GM products in real purchasing situations. Two general conclusions could be drawn. Firstly, the actual purchase behaviour of consumers regarding GM food products does not correspond to their stated attitude when questioned on the subject; and secondly, when GM food products are available on the shelves, consumers are generally willing to buy them. By and large, the level of opposition to GM food rises with the higher income and better education of consumers.

- Although the current GM crops (first generation) were not designed to provide health benefits, studies provide evidence that concentrations of certain mycotoxins are significantly lower in Bt maize than in its conventional isogenic line (linked to reduced insect damage). These mycotoxins can cause adverse health effects in humans. Therefore, consumers, especially in developing countries where mycotoxin contamination is higher, could benefit from the adoption of Bt maize.

Looking Forward: New Crops in the Pipeline and Possible Economic and Social Impacts

- The global pipeline for GM crops is active and expanding: up to 124 GM events are expected to be commercially available by 2015, compared to some 40 GM events released so far. Although existing crops (soy, canola, maize, cotton) and traits (HT, Bt) will still be dominant in 2015 there will be a slight but significant diversification in terms of genetically modified species, but also in terms of traits. Different agronomic traits (e.g. resistance to viruses, improved resistance to diseases and tolerance to abiotic stresses such as drought or high salinity) are expected to increase in importance, as will 'second-generation' crops which will specifically address the needs of consumers, through, for instance, improved fatty acid profile or higher content in beta carotene.

- The coming years will see the emergence of technology providers from Asia as a major source of GM events. This region will be especially active, putting on the market the first GM rice varieties, even if the release of some of the GM rice events in the pipeline a few years ago has been delayed or even cancelled. Most of the rice events close to commercialization are insect resistant varieties, in addition to the biofortified rice called Golden Rice. Nevertheless, in Asia the dynamic of the research pipeline seems unaffected by the uncertainties of governments.

- In the case of Golden Rice, an event genetically modified to express genes that lead to the accumulation of beta carotene in the rice grain, the development is already quite advanced, and a regulatory dossier could be delivered to the authority in the Philippines by 2013. Indeed, among Asian countries, the Philippines and Indonesia might be the ones releasing the first commercial GM rice in the next years.

- Improvement in crop quality may generate nutritional or health benefits for consumers, and thus may change their attitude toward GM crops. Therefore, the new traits incorporated by the GM crops in the pipeline would require new evaluation methods and new socio-economic indicators to assess their impact (e.g. to compare the cost effectiveness of the use of these crops with alternative public health measures).

- Actually, some *ex ante* assessments of the impacts of new GM crops are already available. In the case of Golden Rice, recent studies estimated the reduction in morbidity and mortality potentially generated by the introduction of this crop. Results show a significant beneficial health impact, at a lower cost when compared with alternative public measures. *Ex ante* studies for Bt rice conducted in China estimated a huge internal gain for rice production, even when considering the potential loss of export markets.

- For Europe, developing *ex ante* impact assessments is a priority due to the limited number of GM crops that are available to be studied *ex post*. Examples of successfully applied methodologies are studies predicting the level of adoption and the economic impacts of the introduction of GM maize designed to control the Western Corn Rootworm, a pest that arrived in Central Europe in the 1990s. Bio-economic simulations of this kind should be extended to the main GM crops in the regulatory pipeline.

1 Introduction

Techniques of genetic modification based on recombinant DNA (Deoxyribonucleic acid) have been used in plant breeding since the 1980s and the first crops produced by GM technologies reached commercial cultivation in the mid-1990s. In many countries the existing legislation was not regarded as sufficient to regulate GMOs and so new legislation on GMOs was introduced in the 1980s and 1990s. It generally provides for an authorisation process for experimental and commercial release, import and marketing and use of these new crops including comprehensive risk assessments (environmental and food and feed safety).

In more recent years studies on the socio-economic impact of policies were introduced as an additional support tool for policy makers in decisions in many policy fields. While environmental and health risk assessment is usually an integral and mandatory step in the regulatory process, the carrying out of a socio-economic assessment (SEA) is rather facultative in the authorisation process or is used (*ex post*) to monitor the impact of approved technologies.

The EU GMO legislation provides for *ex post* assessment of the socio-economic implications of deliberate release and placing on the market of GMOs. Under Directive 2001/18/EC[1] the Commission is required to submit a report on the implementation of the Directive including an assessment on the abovementioned subject. At a meeting in December 2008, the Environment Council called to mind the Directive's requirement to submit a specific report on the implementation of the Directive 2001/18/EC and invited Member States to collect and exchange relevant information on the implications of the placing on the market of GMOs[2].

Considering a SEA (*ex ante*) in the authorisation process for GMO cultivation appears to be a possible approach. Regulation (EC) No 1829/2003 asks the Commission to take into account, for the decisions on applications for the authorisation of GMOs, the opinion of the European Food Safety Authority (EFSA), relevant provisions of the Community law and "other legitimate factors relevant to the matter in consideration". The possible consideration of socio-economic factors in the authorisation of GMOs for cultivation was also stressed by Member States in several Environmental and Agricultural Councils[3].

Methodology for environmental and health risk assessments is well-developed and implemented in the regulatory process of GMOs, whereas studies on the socio-economic impact of the cultivation are carried out mainly by academia. However, a recent review[4] revealed that even academic research does not cover all relevant sectors equally (most of the studies focus on the farm level, with fewer studies on the other sectors such as seed, food, feed and consumer) and that methodology has to be developed

1 Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC OJ L 106, 17.4.2001, p. 1–39

2 Working paper to the Commission report on socio-economic implications of GMO cultivation (SANCO/10715/2011): http://ec.europa.eu/food/food/biotechnology/reports_studies/docs/swp_socio_economic_report_GMO_en.pdf

3 Environment Council of 2 March 2009, Agriculture Council of 23 March 2009 and Environment Council of 25 June 2009.

4 Report from the Commission to the European Parliament and the Council on socio-economic implications of GMO cultivation on the basis of Member States contributions, as requested by the Conclusions of the Environment Council of December 2008 (SANCO/10715/2011 Rev.5): http://ec.europa.eu/food/food/biotechnology/reports_studies/docs/socio_economic_report_GMO_en.pdf

further. Currently the global area sown with GM varieties is over 148 million hectares[5], although only some 100,000 ha of GM crops (mainly Bt maize) are cultivated in the EU. Consequently, most studies (especially *ex post* studies) were carried out in countries outside the EU.

In the European Union (EU), the European Commission (EC) recently initiated activities to build up a methodological framework for socio-economic impact assessments, to define the precise socio-economic indicators to be monitored and to establish appropriate rules for data collection. The main purpose of this report is to provide the proceedings of an international workshop on the socio-economic impacts of genetically modified (GM) crops co-organised by the JRC-IPTS and the Food and Agriculture Organization of the United Nations (FAO) as a first step in technical discussions between the Member States and the Commission. However, it also provides information on the background and prospects for future development.

5 James, C. Global Status of Commercialized Biotech/GM Crops: 2010. ISAAA Brief 42. http://www.isaaa.org/resources/publications/briefs/42/default.asp. *International Service for the Acquisition of Agri-Biotech Applications, Ithaca, NY* (2010).

2 This Report

This JRC Scientific and Policy Report provides proceedings of the "International workshop on socio-economic impacts of genetically modified (GM) crops" which was co-organised by the JRC-IPTS and the FAO in Seville on 23-24 November 2011.

The JRC-IPTS has been requested to review for policy makers the main findings of scientists active in this field worldwide in co-operation with the FAO. The objective of this workshop, which was directed at socio-economic experts from the competent authorities of the EU Member States and staff from the EC, was to start technical discussions between the Member States and the Commission to define the factors and indicators necessary to properly capture the impacts of GMOs in the EU.

Chapter 3 provides background information on the Commission report on the socio-economic implications of the cultivation of GMOs and current changes to Directive 2001/18/EC which will give more flexibility and responsibility to Member States concerning decisions on the cultivation of GMOs in their territory. Additionally it reports on a Commission conference on the socio-economic impacts of cultivation of GMOs which was organised in October 2011 and it provides an overview of activities of the JRC-IPTS and the FAO in the field. Chapter 4 is dedicated to the "International workshop on socio-economic impacts of GMO crops" (November 2011). It summarises the main topics presented and the discussions from each of the sessions and discusses the prospects of further research.

The list of the workshop participants and the agenda of the workshop are included in Annex 1 and Annex 2 respectively. Annex 3 contains short papers on the presentations given during the workshop provided by the authors.

3 Background Information

3.1 *Commission report on the socio-economic implications of the cultivation of GMOs, 2011*[6]

In December 2008, the Environment Council invited the Commission and Member States to provide a report on the socio-economic implications of the deliberate release and placing on the market of GMOs. The Commission launched a consultation of the Member States on the socio-economic impact of GMO cultivation via an indicative questionnaire which focused on issues such as economic and social implications, agronomic sustainability and environmental impacts. Alternatively, Member States could send their contributions in other formats.

Data submitted by the Member States originated from a wide range of sources, from peer-reviewed studies to assumptions of individuals. Inputs from different stakeholders had been synthesised by a competent national authority, or an unabridged set of answers from different stakeholders was transmitted directly to the Commission.

The report, which was finalised in 2011, provides a short summary of the main elements of the Member States' contributions. Non-exhaustive compilations of the individual contributions of the Member States are in the Commission's working paper accompanying the report. All the received contributions are available in full on the website of the Commission[7].

Complementary to the results of the consultation with Member States, the report also includes a review of the international scientific literature on the economic and social dimension of GMO cultivation. The references are listed in the working paper accompanying the report. Additionally the report provides a short discussion of the most relevant research projects under the sixth Framework Programmes for Research:

- Results and perspectives on the coexistence and traceability of GM and non GM supply chains (CO-EXTRA – 2005-2009)[8]
- Sustainable introduction of GM crops to European agriculture (SIGMEA 2004-2007)[9]
- Do Europeans buy GMO food? (CONSUMERCHOICE – 2006-2008)[10]

Overall, the report concludes that GMO cultivation in Europe is limited to rather small agricultural areas in a few of the Member States. Seven Member States have past or present experience in cultivating Bt maize MON 810. Romania cultivated herbicide tolerant (HT) soybeans before joining the EU and the cultivation of the GM potato Amflora has been started in three Member States. Consequently, relevant information from *ex post* studies is limited.

Additionally, statistically relevant data on the socio-economic impacts of GMO cultivation

6 Report from the Commission to the European Parliament and the Council on socio-economic implications of GMO cultivation on the basis of Member States contributions, as requested by the Conclusions of the Environment Council of December 2008 (SANCO/10715/2011 Rev.5): http://ec.europa.eu/food/food/biotechnology/reports_studies/docs/socio_economic_report_GMO_en.pdf

7 http://ec.europa.eu/food/food/biotechnology/reports_studies/contributions_en.htm

8 Results and perspectives on the coexistence and traceability of GM and non GM supply chains (CO-EXTRA – 2005-2009) http://www.coextra.eu/

9 Sustainable introduction of GM crops to European agriculture (SIGMEA 2004-2007): http://sigmea.group.shef.ac.uk/

10 Do Europeans buy GMO food? (CONSUMERCHOICE – 2006-2008): http://www.kcl.ac.uk/medicine/research/divisions/dns/projects/consumerchoice/downloadfiles/Chapter01.pdf

in Europe (and also outside Europe) are mainly available at farm level. The socio-economic impacts of GMO cultivation in Europe across the food chain and the society as a whole are often not analysed in an objective manner. On this basis the Commission considered a targeted analysis of specific topics as inappropriate.

The Commission recommends that a robust set of factors should be defined to capture *ex ante* and *ex post* socio-economic consequences over the whole food chain, from seed production to consumers. A methodological framework should be built up to define the precise socio-economic indicators to be monitored and to establish appropriate rules for data collection.

3.2 *A more flexible approach for GMO cultivation under the existing GMO legislation in the EU*

In July 2010 the Commission proposed a package of two series of measures aiming to provide more possibilities for Member States to decide on GMO cultivation.

The first element of this package was the adoption on 10 July 2010 of a new Recommendation on guidelines for the development of national coexistence measures[11], replacing a previous Recommendation from 2003[12]. The new Recommendation provides a more flexible interpretation of Article 26a of Directive 2001/18/EC which allows Member States to adopt measures to avoid the unintended presence of GMOs in other crops. Indeed the new Recommendation recognises that the potential loss of income for producers of particular products, such as organic products, is not necessarily limited to the exceeding of the labelling threshold set at 0.9% in the EU legislation. In certain cases, and depending on market demand and on the respective provisions of national legislation (e.g. some Member States have developed national standards of 'GM-free' labelling), the presence of traces of GMOs in particular food crops – even at a level below 0.9% – may cause economic harm to operators who would wish to market them as not containing GMOs. In those cases, Member States would be able to define measures going beyond the provisions of Directive 2001/18/EC, e.g. measures that aim to reach levels of GMO presence in other crops lower than 0.9%.

The second element of this package is a legislative proposal to the European Parliament (EP) and to the Council aiming to increase the possibility for Member States to restrict or prohibit the cultivation of authorised GMOs in their territory. This proposal which takes the form of the inclusion of a new Article 26b in Directive 2001/18/EC[13] will allow Member States to invoke grounds which are not related to the existence of adverse effects to health or environment to restrict or prohibit GMO cultivation. The legislative proposal is currently being discussed by the EP (EP first reading report adopted on 5 July 2011) and the Council of Ministers.

3.3 *Commission conference on the socio-economic impacts of the cultivation of GMOs (Brussels, October 2011)*

As a follow-up to the publication of the report on the socio-economic impacts of GMO cultivation (see chapter 3.1), the Commission organised a one-day public conference on the matter in Brussels on 18 October 2011. The

11 Commission Recommendation on guidelines for the development of national strategies to avoid the unintended presence of GMOs in conventional and organic crops OJ C 200, 13.07.2010, p. 1-5

12 Commission Recommendation on guidelines for the development of national strategies and best practices to ensure the co-existence of genetically modified crops with conventional and organic farming OJ L189, 29.7.2003, p. 36

13 Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC. OJ L 106, 17.4.2001, p. 1–39

aim of the conference was to explore in further detail the findings of the report, and offer the possibility to Member States, third countries and stakeholders to comment and expose their own views and experience.

The agenda, the presentations and live recording of the conference are provided on the EC website:

http://scic.ec.europa.eu/str/index.php?sessionno=d37124c4c79f357cb02c655671a432fa

http://ec.europa.eu/food/food/biotechnology/docs/gmo_agenda18102011_en.pdf

This conference was part of a series of public debates related to GMOs organised by the Commission in order to engage science, policy and society in a constructive dialogue on this highly complex and challenging issue. A first event was organised in March 2011 on GMO risk assessment and management, which was attended by around 250 participants.

3.4 Research at JRC-IPTS in the field of socio-economic impacts of the cultivation of GMOs in the EU

The Institute for Prospective Technological Studies (IPTS) of the Joint Research Centre (JRC) has been involved in research on the socio-economic impact of certain traits of GM crops since 2004, which began with a review on the economic impact of dominant GM crops worldwide[14].

An *ex post* study at farm level on the adoption and performance of Bt maize based on a survey of farmers in three provinces of Spain was carried out in 2005 and the data evaluated in the following years[15, 16, 17]. A further *ex post* study on Bt maize in three countries in the EU and pilot *ex ante* studies on HT rape seed, HT sugar beet and HT maize were carried out in 2009-2010. The data of the *ex post* study are currently being evaluated.

In parallel, the IPTS started to work in the field of coexistence. In the framework of the Coexistence Bureau, which was established at the IPTS in 2007, a best practice document for the coexistence of GM crops with conventional and organic farming[18] was elaborated in cooperation with experts from the Member States. A further publication discusses distances needed to limit cross-fertilization between GM and conventional maize in Europe[19]. In the coming years, the IPTS will carry out a study on the costs of coexistence measures in the framework of the project "Practical implementation of coexistence in Europe" (PRICE) under the seventh Framework Programme.

3.5 FAO research in the field of socio-economic impacts of the cultivation of GMOs in developing countries

The FAO's overall mandate is to support Governments of Members in achieving food security. The FAO's mandate regarding

14 Gómez-Barbero, M., & Rodríguez-Cerezo, E. (2006). Economic Impact of Dominant GM Crops Worldwide: a review. Technical Report Series. JRC Technical Report, EUR 22547 EN, European Commission, Joint Research Centre, 2006

15 Gómez-Barbero, M., Berbel, J., Rodríguez-Cerezo, E. Adoption and performance of the first GM crop introduced in EU agriculture: Bt maize in Spain. Technical Report. JRC Technical Report, EUR 22778 EN, European Commission, Joint Research Centre, 2008

16 Gómez-Barbero, M., Berbel, J., Rodríguez-Cerezo, E. Bt corn in Spain – the performance of the EU's first GM crop, Correspondence, Nature Biotechnology 26, 384-386 (2008).

17 Areal, F.J., Riesgo, L. and Rodrigez-Cerezo, E. Attitudes of European farmers towards GM crops adoption. Plant Biotechnology Journal (in press).

18 Czarnak-Klos, M., Rodríguez-Cerezo, E. European Coexistence Bureau (ECoB): Best Practice Document for coexistence of genetically modified crops with conventional and organic farming: 1. Maize crop production. JRC Scientific and Technical Reports, EUR 24509, European Commission, Joint Research Centre, 2010

19 Riesgo, L., Areal, F.J., Sanvido, O., Rodríguez-Cerezo, E. Distances needed to limit cross-fertilization between GM and conventional maize in Europe. Nature Biotechnology, 28, 780-782 (2010)

agricultural biotechnologies cuts across the Organization's global goals of providing support to Member Governments in producing sufficient safe and nutritious food; ensuring people have the income and means to access food through sustainable livelihoods; and managing natural resources sustainably.

The FAO undertakes four types of activities in relation to agricultural biotechnologies:

- The FAO provides Members with legal and technical advice on areas such as the development of national biotechnology strategies and the development of biosafety frameworks.[20]
- It assists Members with capacity development in various aspects of agricultural biotechnologies, often in collaboration with a range of partners, including other UN agencies and the research centres of the Consultative Group on International Agricultural Research (CGIAR).
- The FAO serves as a meeting place for nations, facilitates the development of international standards and helps frame international conventions and agreements, as well as hosting major conferences, technical meetings and expert consultations.[20] For example, the FAO hosts the Secretariats of several intergovernmental bodies/treaties dealing with some biotechnology-related issues.[21]
- In recent years the FAO has been at the forefront of providing high-quality, up-to-date, balanced science-based information about agricultural biotechnologies to its Member countries. In particular, the FAO has been active in publishing science-based, peer-reviewed analyses of the socio-economic impacts of transgenic crops in developing countries.[22, 23, 24, 25, 26]

20 FAO. 2011. Biotechnologies for agricultural development: Proceedings of the FAO international technical conference on 'Agricultural biotechnologies in developing countries: Options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change' (ABDC-10). http://www.fao.org/docrep/014/i2300e/i2300e00.htm.

21 For example, FAO has assisted countries such as Bangladesh, Paraguay, Sri Lanka and Swaziland to develop their national biotechnology policies and strategies.

22 The Commission on Genetic Resources for Food and Agriculture, the International Plant Protection Convention, the International Treaty on Plant Genetic Resources for Food and Agriculture and the Joint FAO/WHO Codex Alimentarius Commission.

23 Raney, T. and I. Matuschke. 2011. Genetically modified crops in developing countries, in Carter, C., G. Moschini and I. Sheldon, eds. Genetically Modified Food and Global Welfare. UK: Emerald.

24 Raney, T. and Pingali, P. 2007. Sowing a Gene Revolution. Scientific American. September 2007. 29 (3):104-111.

25 Evenson, R. and Raney, T. (eds.) 2007. The Political Economy of GM Foods. An Elgar Reference Collection. Cheltenham, UK and Northampton, MA, US: Edgar Elgar Publishing.

26 Raney, T. 2006. Economic impact of transgenic crops in developing countries. Current Opinion in Biotechnology. Vol. 17, Issue 2, pp 1-5.

27 FAO. 2004. Agricultural biotechnology: Meeting the needs of the poor? The State of Food and Agriculture, 2003-04.

4 The Workshop

An international workshop took place on 23-34 November 2011 in Seville, Spain which was directed at socio-economic experts from the competent authorities of the EU Member States and staff from the EC (see chapter 2).

This workshop brought together leading experts in the field to present the results of their research and to discuss experiences and possible further development. Additionally presentations and discussions on how socio-economic considerations can be (and are currently) used by some countries in decision making and authorisation of GMOs were included. The coverage was worldwide and ranged from farm level to consumer impacts. The high percentage of invited speakers based in countries outside the EU reflects the limited EU experience in the cultivation of GM crops.

Chapters 4.1 to 4.7 summarise the main topics presented and the discussions from each of the sessions and discusses the prospects for further research. The list of participants and the agenda are included in Annexes 1 and 2 of this report. Annex 3 includes short papers for all presentations.

4.1 *Session 1: Adoption of GM crop varieties and socio-economic impacts on farmers*

Presentations:

Global status of GM crop adoption and review of impacts on developing world's farmers	Matin Qaim, Universität Göttingen, Germany
Adoption and impacts at farm level in the USA	Wallace Huffman, Iowa State University, USA
The case of Bt maize in Europe	Emilio Rodriguez Cerezo, European Commission, JRC-IPTS, Spain
Challenges in measuring the economic impacts of biotech crops on farms in developing agriculture	Melinda Smale, Michigan State University, USA

Main topics presented:

Global adoption of GM crops and socio-economic impact

The main objective of this session was to provide the most recent research findings related to the adoption rate and the socio-economic impacts of GM crops at farm level, both in developing and in industrialized countries. Also, the methodological difficulties of measuring socio-economic impacts at farm level, notably in developing countries, were discussed.

Although controversy persists, farmers worldwide are increasingly adopting GM crops. The first GM varieties were commercially released in the USA in 1996, and in 2010 148 million hectares in 29 countries were covered by GM crops, an area that represents approximately 10% of the world cropped area. This dramatic expansion makes GM crops one of the fastest adopted technologies in the history of agriculture.

As for geographical distribution, the USA is still leading and represents 45% of the global GM area, and together with Canada (6% of the global GM area) they account for almost the entire GM area grown in industrialized countries, since among the countries of the European Union only Spain cultivates GM maize on a significant (but still relatively small) scale. But countries in the developing world now represent almost half of the global GM area, notably Brazil (17%), Argentina (16%), India (6%) and China (2.5%).

Despite the increasing cultivation of GM crops worldwide, the diversity of GM plants is still very low, in terms of crops and traits. Four crops represent virtually the whole biotech area. The first of them, namely the Herbicide Tolerant (HT) soybean, accounts for half of the global GM area, mostly in Northern and Southern America. Maize is second, and covers 31% of the global GM area. GM traits introduced in maize are either HT, Insect Resistant (IR or Bt for *Bacillus thuringiensis*, a soil bacterium whose genes conferring a resistance to insects were inserted into the maize DNA), or stacked, i.e. a combination of the two previous traits. GM cotton (HT, BT or stacked), grown mainly in India, China, South Africa and in the USA, covers 14% of the global biotech area, whereas HT canola is grown on 5% of the global biotech area, primarily in North American countries. The other GM crops commercially released so far (such as alfalfa, sugar beet, papaya, potato, squash, sweet pepper), are still confined to a few countries and to very small areas.

The **HT soybean** has been very quickly and extensively adopted in countries where it is available to farmers. Almost 100% of soy in Argentina and 93% in the USA is HT. In both countries, adoption is associated with small and generally insignificant yield effects, and in the USA with no significant change in the use of agricultural chemicals. In South America, there have been some increases in herbicide use, since herbicides are being substituted for tillage. However, the herbicides used in HT soybeans (primarily glyphosate but also some glufosinate) are generally less toxic than those used on conventional soybeans. Profits associated with the adoption of HT soybeans for farmers are generally small, but larger in South America than in North America, reflecting differences in Intellectual Property Rights schemes. While in the USA the cost reductions for farmers (herbicide cost and operation cost) are essentially offset by the technology fee charged by the seed companies, in South America the latter is much lower due to the institutional environment and to the re-use of farm seed.

However, in both regions farmers have found the managerial benefits of HT soybeans to be significant, and the extremely fast adoption rate is generally better explained by the considerable ease of use, efficiency and flexibility that HT soybeans confer for weed control than by direct economic considerations. The technology is time-saving for farmers, and also has agronomic advantages: it reduces the risk of an unsuccessful weeding and facilitates soil conservation techniques, such as no-till practices. In Argentina, it also enables double cropping i.e. soybeans planted as a second crop after wheat, thus using available farmland more efficiently (and reducing further area expansion). This is one of the main reasons behind the large increase in production of soybeans from South America.

However, recent empirical evidence shows that in Argentina the average profit gain through HT soybean adoption was about 23 USD per hectare. As for the USA, a recent study conducted in the Midwest shows that the adoption of GM soybeans tends to reduce the rate of use of all types of variable inputs (capital, labour, energy, chemicals and other materials) and generates in the mid-term a benefit-cost ratio of about 3.6.

There are a number of questions related to the spread of HT soybeans all around the world, since more than 77% of the global soybean area is GM. HT soybeans imply a reduction in the toxicity of the herbicides used, in tillage and probably in greenhouse gases (GHG), but may also promote soy monoculture and favour the outbreak of weed resistance. By consequence, best practices concerning the crop and technology rotation may be required in the future to enhance the sustainability of the soybean production. Additionally, this technology may not meet the needs of small-scale farmers, since they often weed manually and thus do not apply herbicides.

GM maize is the GM plant cultivated in the largest number of countries (16; six of which are in the EU). At the global level, GM maize represents slightly more than a quarter of the total area covered by maize. In the USA, its adoption started slowly but represents 86% of the total maize area (when considering Bt maize, HT maize and stacks together). In this country, cultivation of GM (when compared to conventional maize) is associated with a small but significant increase in yield, which is higher for stacked varieties, and with a reduction in the use of insecticides. In Midwestern US States, output effects of the adoption of GM maize varieties are shown to be insignificant but the rate of use of all input groups (capital, labour, energy, chemicals and other materials) tended to decline, leading to a benefit-cost ratio of roughly 52, which supports future increased intensity of use of GM maize.

Bt maize is the only GM crop grown in the EU in significant amounts, and 90% of that production takes place in Spain. Detailed surveys conduced in 2005 and in 2009 report that Spanish farmers cultivating Bt maize experience no significant changes in costs, the reduction in insecticide costs being offset by the higher price for Bt maize seed. However, Bt farmers do observe a substantial increase in yield, by 11.4% on average in 2009, resulting in a gain in partial gross margin of 195 EUR/ha/year.

In circumstances where insect pests were not effectively controlled by chemicals prior to the adoption of Bt corn, the main effect of switching to Bt will be a reduction in crop damage and thus a raise in yield. This may be the common situation in developing countries, where the use of insecticides was restrained by the availability of suitable products or by technical, financial or institutional constraints. Effective yield-increasing effects of Bt maize in the order of 11% (South Africa) or even 34% (Philippines) have been observed, resulting in a profit increase of 42 USD/ha and 53 USD/ha, respectively.

Bt cotton is by far the most commonly studied GM crop in socio-economic terms, probably because it has been adopted by a large number of small-scale farmers in developing countries and thus raises issues of rural development, poverty or dependence, in addition to the more common environmental concerns associated with GM crops. India is the first country in the world in terms of area of Bt cotton, followed by China and the USA. In India, 90% of the whole cotton area is Bt, and there are more than 6 million smallholder farmers growing it, with an average cotton area of 1.5 ha each. Though different studies vary somewhat in terms of the concrete effects observed, most of them find positive agronomic and economic effects for Bt cotton farmers. The common feature is that the cultivation of Bt cotton strongly reduces the use of insecticide (by 65% in China and 41% in India) and increases yields (by 24% in China and 37% in India), as farmers were not fully effective in controlling pests before the adoption of GM cotton. Although the cost of the Bt cotton seed is higher (for instance, +166% in India), Bt cotton farmers make an important additional profit, between 135 USD per ha (in India) and 470 USD per ha (in China).

Also indirect benefits of the Bt technology were found. In India, a study conducted at village level concludes that the positive spillover of Bt cotton cultivation for the local economy (in terms of additional household income) was almost comparable to the direct benefits for farmers. For the country as a whole, this would imply a direct economic gain of 1.3 billion USD, which rises to 2.3 billion if the indirect effects for the rural economy are added. Additionally, health benefits have been reported. An 80% reduction in the number of farmer acute poisoning events was found following the adoption of Bt cotton. These strong positive effects of Bt cotton cultivation have been observed in many countries worldwide, the benefits in tropical countries being usually more important because of higher pest pressure.

Methodological challenges

A number of methodological issues are associated with the socio-economic assessment of GM crops at farm level, especially in developing countries, where researchers typically cannot rely on agricultural census data or samples representative of the whole country to generate information. Researchers must collect data in personal interviews with farmers using specially designed surveys which are costly and challenging to implement because of logistical considerations. Random sampling may not be feasible because of the political sensitivity of GM crops and the unwillingness of community leaders and individual farmers to respond to questions. During the first decade of published studies, the most commonly applied methodologies were partial budgets and econometric models of farm production, in which researchers tested hypotheses related to the yield advantages, labour and pesticide savings associated with adoption.

As a recent survey conducted in the Midwestern states of the USA shows, fitting a production function may also aid identification of impacts on each input type separately, as it allows the modeller to relate outputs to inputs and technology econometrically. When data for prices of inputs and outputs are available, the estimation of output supply and input demand equations provides useful information about the technology effects.

Data quality was a major limitation of early studies, where samples were typically small, field observation periods were brief, and estimates of key parameters were often based on farmers' recall. With respect to partial budgeting, early studies often suffered conceptual limitations, such as measurement of gross rather than net margins, and not considering land and labour costs. Some of the most advanced studies treat risk and uncertainty using stochastic budgeting. Perhaps the most critical concern has been self-selection bias, i.e. the fact that farmers adopting the GM technology may also be the most efficient, or those with greater endowments and better access to markets or information. More recent studies have addressed self-selection bias in various ways.

Under some circumstances, the variability in the Bt gene expression may also be challenging. It is notably the case in developing countries, like China or India, where the high number of commercial varieties available for Bt cotton, combined with the existence of a black market and counterfeiting of seeds, may lead to a high variation in the efficiency of Bt cotton in controlling pests. As this information is not easily available, it is therefore also difficult to include it into an econometric model. Additionally, the decision to grow a GM crop may be endogenous, and explained by other factors which are unobservable or not integrated into the model (like pest pressure for instance). These methodological issues can be addressed by using advanced econometrical techniques (that correct the endogeneity problem by, for instance, introducing an instrumental variable), as recent surveys have done.

Discussion:

It was noted that the general public does not usually understand the difference in quality of publications. Laypersons are generally not able to distinguish between partisan reports and scientific peer-reviewed studies, which indeed they are hardly aware of. Therefore, contradicting studies from different origins and with opposing results usually lead to confusion.

The sustainability of the benefits over time was also questioned, and it will depend on the adoption of the "best agricultural practices", either for producers of conventional or GM crops, in particular to prevent the advent of resistance to weeds or pests that will make the technology fail. Until now, few cases of weed or insect resistance have been reported. The issue of the environmental impacts of GM crops and how to introduce externalities in economic analyses is under debate, as well as the way to consider the impacts of GM crops on biodiversity.

Experts stressed the importance of conducting more robust studies. However, they also agreed that the overall conclusions presented so far remain valid even taking into account the need for improved methodologies to highlight some of the pending, more subtle issues. It was noted that the most important step in the development of a study is the design of the sample, which has to address potential selection biases.

It was stated that experts in the EU will face similar challenges as in developing countries when approaching farmers in the context of a study. In some areas, because of the limited number of non-adopters and the high sensitivity of the issue it will be very difficult to target a representative sample of adopters and non-adopters. On the other hand, an expert from the USA noted that such kinds of socio-economic assessments are now conducted less frequently, probably because of the decreasing interest of journals in publishing these studies and the difficulty to find non-adopters (for comparison) in areas with a very high adoption rate.

Prospects:

Participants all agreed that more independent, *ex post* farm studies on the impacts of GM crops are necessary in order to move forward the scientific knowledge in the field of the socio-economic assessment of GM plants. These studies need to rely on surveys at farm level, in order to capture the real-life effects of GM crops on farmers' practices, and to take into consideration the consequences for the agricultural production system as a whole (and not only the yield or the cost-reduction effects for instance, but also labour effects and flexibility of work). Further research will also have to cover more crops, traits and countries than in the previous studies, relying on advanced methodologies in terms of sampling and data analysis.

4.2 *Session 2: Aggregated and global impacts of GM technology in agriculture.*

Presentations:

Welfare creation and distribution	Carl Pray, Rutgers University, New Brunswick, USA
Impacts on global productivity and world food prices	David Zilberman, University of California, Berkeley, USA

Main topics presented:

Potential beneficiaries and losers - globally

The main objective of this session was to give an overview of the effects of GM crops outside the farm gate. Cultivation of GM crops takes place in a global market which gives rise to effects both upstream and downstream of the farming sector. The affected actors can be divided into two groups, the winners and the losers.

The potential beneficiaries along the supply chain include the seed and biotechnology industry, through higher seed sales, and farmers through increased income and, in some cases, improved health status. The different downstream users of agricultural outputs such as the food industry, the feed industry, the livestock industry and the textile industry increase profits by buying higher value agricultural products at a lower cost. Finally consumers benefit from lower prices for food and fibre and reap the benefits from biofuels.

As for the potential losers, manufactures of competitive inputs (insecticides, agrochemicals) lose market shares and non-adopting farmers have a competitive disadvantage which may lead to losses. The latter can either be conventional farmers not adopting the technology who face lower output prices or producers who lose markets because of admixture of GM crops (see session 3 of coexistence).

Although all these effects are known qualitatively, few studies assess these effects in an integrated quantitative way. The majority only focus on specific aspects of the problem, evaluating the impacts for certain stakeholders or certain markets.

Economic models have been developed to estimate the global economic welfare creation of GM cultivation and the distribution of its benefits among stakeholders. The HT soybean is one of the crops being researched and has been estimated to create benefits of around 3 billion USD globally each year. According to the results of model calculations, 50% of this amount accrues to processors and consumers while farmers capture about 28%. The remaining 22% seem to be extracted by the innovating biotechnology sector. Disaggregated data evidence suggests that institutional factors influence this distribution among stakeholders to a great extent. In developed countries, where strong intellectual property rights exist, the share of the benefits of the biotechnology sector is significantly higher than in developing countries. In the case of the cultivation of soybeans in the USA, the biotechnology sector is able to extract 57% of the arising benefits.

Case studies covering different GM crops and countries indicate that the biotechnology sector captures 30% to 60% of the generated benefits in developed countries. In countries with a lower degree of patent protection however, farmers secure 80%-90% of the benefits, leading to higher domestic benefits from the technology. Moreover, farmers in developing countries face a higher potential pay-off from GM technology due to several reasons. Pest pressure is often greater in developing countries and the pests are often not adequately controlled in conventional farming. Hence the introduction of a GM crop diminishing pest damages may result in high yield benefits. Furthermore, a multiplicative effect on benefits may occur: a farmer adopting GM crops expects higher yields and will therefore be attracted to buy underused inputs such as fertilizers, eventually resulting in even higher yield benefits. A recent study spanning 1996-2008 and 8 crops confirms these assumptions, estimating a yield increase in cotton, maize and soybeans following the adoption of GM crops that is significantly higher in developing countries. The higher economic and agronomic productivity of GM crops may also have affected global land use and carbon sequestration, but the extent of this effect is currently only supported by a few studies.

Yield benefits and cost reductions are also important in the global markets as spill-over effects influence prices, even for countries not cultivating GM crops but importing them. For instance, the EU does not allow production of HT soybeans but in 2009 Europe imported, primarily for animal feed, 23 million tons of soy meal and 12.6 million tons of soybeans from South America and the USA, mostly HT soybeans.

The price effects of GM crop adoption are substantial, having a direct impact on food security and availability. Models estimate that the increases in world food prices would have been significantly higher in the absence of GM cultivation, by 10% to 30% depending on the crop and the underlying assumptions. These price increases would have been especially devastating during the food commodity price peak in 2008. This price effect benefits all consumers globally through trade. Of particular significance is the increase in supply of soybeans due to the use of herbicide tolerant varieties that were able to meet the growing demand for meat in Asia during the last decade. Studies also estimate that if GM varieties had been adopted in Africa and

Europe, the reduction of price effect would have countered some of the price increases associated with the introduction of biofuel.

The benefits captured by direct customers differ depending on the trait and the geographic area. For cotton, benefits ultimately accrue to consumers through reduced textile prices, estimated at around 1%. For maize in the EU, USA, Brazil and Argentina the food, feed and biofuel industry are the primary customers who transfer the price reduction to consumers. In the case of maize in Africa and Central America price reductions are beneficial to all consumers as it is the staple grain for millions of consumers. However, very limited studies are available on the aggregated impact of the technology on the consumer side and its distribution to the different groups of consumers.

Global and sectorial shifts of benefits over time

The combination of institutional and environmental effects led to a geographic shift of farmer benefits from the initial situation where benefits were concentrated in the USA, Canada and Argentina to a situation where small farmers in a variety of developing countries obtain more benefits from the technology. Farmers' benefits from insect resistant maize are still highest in the USA, but most of the benefits from HT soybeans are obtained by farmers in Argentina and Brazil and the benefits from IR cotton mainly accrue to farmers in China and India.

This shift in benefits may have important secondary effects in the long term. One effect that has recently been observed is a shift in R&D investment in biotechnology to developing countries following the rapid growth in sales. The technology fees give biotech companies money to invest in local research and the rapid growth in the market for GM holds the promise of greater profits in the future. In the last ten years Monsanto has invested in major biotech research facilities in Brazil, India and China. DuPont has invested in basic biotechnology laboratories in China and India. In addition there have been major investments in biotechnology research by multinationals based in the developing world such as Advanta (India) and Pannar (South Africa), and by national firms particularly in India, and the governments of China, Brazil and India. These programs are developing technology for the needs of the developing world – GM white maize in South Africa and hundreds of hybrids of Bt cotton to suit local agricultural conditions in India have already been developed by the private sector. DuPont, Bayer Agrosciences and other key biotech companies have major rice research programs for Asia which were virtually non-existent 20 years ago. In India alone private seed R&D grew 18 times between 1995 and 2008. This creation of high technology jobs is expected to have important multipliers on local economies.

Moreover, the shift in benefits from the agro-chemical industry and conventional seed producers to the biotechnology industry translates to a shift in R&D between these sectors. The effects of this shift are still unclear. One of the concerns often raised is whether this shift leads to concentration in a seed sector and a decreased interest in conventional breeding.

Discussion:

The issue of concentration in the seed sector was raised. The experts reiterated the opinion that this issue is difficult to assess and the concentration is highly dependent on the specific context. Generally, the high cost of approval seems to make it impossible for small companies to engage in the GM regulatory process, possibly leading to concentration in the sector and IP rights presumably contribute to this development. However, in the USA no extra concentration in the seed sector has been found since the introduction of GM crops for maize, and concentration increased for soy but decreased for cotton, and the concentration for the supply of gene events recently decreased. In developing countries (Brazil, India and China) the possible increase in concentration is counteracted both through small private companies or (para-)

statal investment. In order to fully understand the effect of GM regulation on the concentration in the seed sector it is essential to separate it from other factors such as the impact of IP rights.

Since some speakers mentioned benefits of GM crops for small scale farmers, a question on the definition of small scale farming was raised. Participants agreed that this is a context-specific definition. It was noted that the mere size of the farm was not decisive but that other factors, such as the access to resources and markets, were important. GM cultivation as such is regarded as scale neutral as both large and small farms can profit.

Finally the importance of GM cultivation for food security was stressed by one of the experts. Adoption of GM cultivation in additional countries (such as in the EU and Africa) could increase agricultural productivity. However, although at first glance consumers would profit from decreased world prices concern was raised that the adoption of GM cultivation in the EU could lower the export opportunities for developing countries. The expert replied that this issue has not yet been studied in depth and is therefore difficult to assess as it is strongly dependent on assumptions about future approval of crops in different areas of the world. He noted that food demand is expected to increase in the coming decades, presumably leaving export markets for developing countries intact.

Prospects:

The session stressed the need for more studies assessing the impact of GM crops on a global scale and in a global market. Most of the present studies focus on a specific aspect and fail to capture spill-over effects. A first step would be to broaden the scope of the crops and assess different crops at the same time, as substitution may occur. Even more interesting for policymakers would be a more in-depth insight into the effects on global consumers and on those sectors in the economy that might be losing out from the introduction of GM technologies. Finally, more attention should be given to irreversible long-term effects such as the impact on climate change and the shift in R&D investment. Only by incorporating these secondary effects can a full understanding of the impact of GM crops on society be obtained.

4.3 *Session 3: Economics of segregation/coexistence of supply chain.*

Presentations:

Case studies of supply chain analysis and segregation costs in the EU	Klaus Menrad and Andreas Gabriel, University Weihenstephan, Straubing, Germany
Coexistence of GM and non-GM supply chains in the EU: policy framework and economic aspects	Justus Wesseler, Technical University Munich, Germany
EU coexistence policies may shape future adoption of GM technology by EU farmers	Francisco Areal, Laura Riesgo* and Emilio Rodriguez Cerezo European Commission, JRC-IPTS
Managing GM free label	Christoph Zimmer, VLOG, Berlin, Germany
The global agricultural supply chain: feasibility, costs and opportunities of coexistence of GM and non-GM commodities	Nicholas Kalaitzandonakes, Univ. Missouri, USA

Main topics presented:

The main objective of this session was to discuss the feasibility and costs of different coexistence and segregation systems, be they regulatory or market-driven. This topic is particularly important for the EU given its regulatory framework.

Regulation and private standards

The cultivation and marketing of GM crops is regulated in most countries. Freedom of choice for both consumers and farmers is one of the major arguments used for justifying additional regulations. Different public policies govern the segregation and coexistence between GM and conventional food and feed supply chains. In some countries market actors complement these regulations with private standards which require even stricter segregation rules than required by the respective governments. For example, the EU-based food industry and retailers are hesitant to accept GM products and are willing to accept higher costs to avoid mandatory GM labelling, while most of the EU feed industry accepts GM raw materials, relying solely on the legal thresholds for labelling.

Segregation costs

Segregation and coexistence policies result in additional costs but may also generate consumer benefits (consumer choice, creation of niche markets for non-GM labelled products etc). Until now, empirical studies mostly assessed the costs for farmers and their downstream supply chains in many parts of the world.

At the **farm level**, EU Member States apply coexistence policies for GM and non-GM farming, consisting of a set of *ex ante* regulations and *ex post* liabilities. The EU has decided that the GM farmer should take the measures (usually administrative measures or technical measures such as isolation distances) and bear the liability.

This arrangement increases the cost of adoption of GM crops. Moreover, research shows that these regulations have a tendency to discriminate against small farmers (unable to implement isolation distances) and may also have a regional and landscape effect on adoption through the so-called domino effect.

The costs and feasibility of coexistence depend, to a large extent, on the threshold set for adventitious presence of GM crops in non-GM production. Beside the legal threshold for labelling (0.9%), some private operators in the EU (retailers or organic industry) demand higher private standards (0.1%), making coexistence even more expensive or even infeasible. Farmers can minimize coexistence costs by cooperating and spatially aggregating the production of GM and non-GM crops (e.g. "Production zones" in Portugal). However, to allow for this, the *ex ante* regulations have to be flexible. Rigid regulations hamper GM adoption, as shown both theoretically and econometrically in six EU member states.

The general policy of European **food industry and retailers** to avoid GM raw materials can be achieved by sourcing ingredients from certified non-GM markets (at higher costs) and separating GM and non-GM ingredients in their processing facilities. Separation can be achieved through different approaches. A first solution is to separate GM and non-GM crops spatially through separated production facilities or by splitting up production lines in one facility. Alternatively temporal separation can be applied, e.g. by producing first the non-GM line followed by the GM line. This implies allowing enough time for cleaning the facility in between batches.

Costs are connected to both approaches. Case studies show that the type and complexity of the supply chain to a great extent influence the segregation costs. The total additional costs of coexistence and product segregation systems can rise to almost 13% of production turnover for non-GM rapeseed oil in Germany. In case of non-GM sugar production the additional costs amount to 2%-5% and in the case of non-GM wheat starch production to 8%-13%. When comparing supply chains in different countries, different cost structures can be found because of special legal frameworks and company (infra)structure. Therefore, variable additional costs for non-GM rapeseed oil were estimated for Denmark

(8.3% of turnover), Switzerland (5.3%) or Poland (3.6%). In the case of highly processed goods the share of segregation costs in the turnover tends to be lower. For a frozen pizza producer the coexistence costs represent only 0.6% of the turnover of a reference company. The case studies reveal that the ability of food processors, in terms of infrastructure and resources endowment, to deliver both GM and non-GM commodities in parallel determines the feasibility of coexistence. The conversion to parallel production will be difficult to manage, especially for companies with smaller facilities. Only a few European companies have the opportunity for specialization and supplying the market with GM and non-GM food products if the demand situation changes. These results show that the costs of coexistence and the feasibility in the supply chain should be considered on a case-by-case basis. Very little empirical information on these costs is available and often constitutes proprietary business data which makes it a challenging subject for research.

The perceived demand of European consumers for non-GM food has created new niche markets for the food industry. In Germany, the government introduced a new "Ohne Gentechnik" (Without Genetically Engineering) law (initially for meat and milk products) which specifies requirements that products have to fulfil in order to be labelled GM free. In 2009 the Federal Ministry of Food, Agriculture and Consumer Protection introduced a GM free logo which is now managed by the stakeholders, by VLOG (Verband Lebensmittel ohne Gentechnik) which was founded in 2010. Since the launch of the GM free label there has been a steady growth in participants. According to a representative of VLOG, the goal of the label is ambitious with a market penetration of 80% in the egg market by 2012 and over 50% in the milk market by 2014. Non-GM production incurs higher costs that have to be compensated in the market, but it also faces increased uncertainty, as the risk of contamination and price volatility is higher in non-GM input markets. Economic analyses showed that German farmers get a small price premium from the scheme to cover their extra costs (some 3-4% of the price for producers of milk from cows fed with "non-GM" feed). For food processors, the label adds a perceived quality attribute which allows a price premium and potentially an increased turnover. No cost-benefit analysis of the scheme is available for the food industry. It is interesting to note that the German scheme allows "GM free" labelling of products for which a GM counterpart does not exist (i.e. apples). This could be considered as disinformation and just a market opportunity. Overall these types of private labelling and schemes have not yet been comprehensively studied.

Implications on international trade

Food/feed ingredients are highly traded commodities and Europe is a top importer for maize, soybeans and soybean meal. Over 80% and 90% of traded maize and soybeans (including soy meal) respectively originates from countries that grow GM maize and soybeans. To serve the non-GM grain markets worldwide (mainly Japan and the EU), grain traders use different types of spatial and temporal separation measures. However, some bottlenecks exist, e.g. the low number of ports used to ship the commodities from all over America or the certified seeds. The major determinant of the costs is the level set for the threshold for GM traces in the non-GM end product. For the moment the market reveals price premiums that cover the incremental costs for the entire supply chain.

Adventitious presence of non-approved GM crops in the non-GM supply chain did result in trade distortions and higher costs for European importers and processors. Indeed, the world prices for non-GM segregated grains have significantly increased in recent years.

Discussion:

There was notable interest in the presented case study on the German GM free label. A similar scheme seems to exist in Finland and Austria, and

France is also about to introduce a GM free label. The French participant stated that their national scheme excludes GM free claims for products where no GM counterpart exists. MS' experts questioned the involvement of the German government in the scheme. The expert indicated support from the government on two levels. The government initially aided the association through a subsidy for communication measures (webpage). Furthermore, the German government is responsible for testing and monitoring the compliance with the regulation of GM free labelling.

The question of how production areas outside the EU manage farm-level coexistence in the absence of regulations was raised. In Brazil non-GM soy is grown in particular regions and hence spatial clustering is inherent. It was suggested that institutional factors, such as the regional demand for GMO crops by traders and the presence of ports, gave rise to this development. Until 2004 the premiums received for non-GM soy were obtained by the traders, and since 2011 there is also a premium for the farmer. In the USA farms are very large and have no problem implementing isolation distances and border rows to manage coexistence if necessary.

The existence of a price premium for non-GM crops in the market could encourage countries aiming to penetrate this market. Brazil tried this in the past but was not able to attain a significant premium and hence changed to GM production. Some African countries however have an incentive to stay non-GM as exports are very sectoral and only aimed at the European market.

Finally the question was raised as to why thresholds differ between countries as it has been proven to be a main driver of the coexistence costs. The conclusion was that it is often more a political choice than a rational decision.

Prospects:

At the farm level there is a need for a better understanding of the impact of different coexistence regulations on the adoption and the diffusion of GM technology. This information is important for the design of efficient coexistence measures. From the other side of the spectrum it is important to get an insight into the working of non-GM markets. The demand in these markets and the resulting price premium will determine how the food/feed industry will react and how segregation in the supply chain will be achieved, from farm to fork. An integrated model with endogenous price mechanisms could be a way to achieve these goals.

4.4 *Session 4: Socio economic impacts of GM crops: examples of use in decision-making.*

Presentations:

Socio economic considerations of GM crops in the context of the Cartagena Protocol of Biosafety- CBD	José Falck-Zepeda, IFPRI, Washington, USA
Socioeconomic assessment - a requirement for authorisation for cultivation of GM crops in Argentina	Carmen Vicién, University of Buenos Aires, Argentina

Main topics presented:

Session 4 reviewed the implications of the use of a socio-economic assessment (SEA) of GM crops in regulatory decision making systems. An international example, SEA in the framework of the Cartagena Protocol of Biosafety (CPB), and a national example, SEA as an integral part of the GM regulatory process in Argentina, were presented.

The Cartagena Protocol on Biosafety (CPB)

The 2000 Cartagena Protocol on Biosafety (CPB) - part of the UN Convention of Biological Diversity – initially focused mainly on assessment procedures for environmental safety and transboundary movements of living GMOs and was later expanded to include food/feed safety and cultivation decisions for commercialization. Article 26.1 of the CPB stipulates that for decisions on GMO imports, countries may consider SEAs of the impact of GMOs on the conservation and sustainable use of biodiversity, especially with regard to the value of biological diversity to indigenous and local communities. When implementing the CPB in national legislation, many countries have gone beyond the contents of Article 26.1 by introducing other considerations, such as social, ethical or philosophical aspects.

When a country includes a SEA in the GMO biosafety regulatory process it has to decide if the SEA should be voluntary or mandatory, if it should be carried out for approval (*ex ante*) and/or for post-release monitoring (*ex post*) and which methodology should be applied. For *ex ante* studies the choice of methods is limited and they will necessarily be based on projections and assumptions. Furthermore, countries will need to decide on the scope of the SEA (narrow interpretation of Article 26.1 of the CPB or broader set of assessments) and who will be the body responsible for conducting the SEA (e.g. government or third party experts). Finally, they will need to specify the decision making rules and standards to be used in the process.

Comparison of the current approaches to include SEAs in the GMO regulatory process in Argentina, Brazil and China shows significant differences. In Argentina, a SEA is mandatory and comprises the *ex ante* assessment of economic impacts on trade and competitiveness. Brazil has introduced a non-mandatory SEA with an open scope and it is decided on a case-by-case basis whether it is to be used (after the biosafety assessment is completed and only if specific issues are identified). In both countries government experts are responsible for carrying out the assessment. In China, a SEA is currently not included in the guidelines and regulations, it may be conducted by third party experts and the scope is not defined.

As for potential implications of the introduction of SEAs in the regulatory process, SEAs will provide more and better information about the technological impact for the decision making process and may help to avoid the adoption of inefficient technologies. However, the regulatory compliance costs will increase, regulatory delays are possible and, if standards are not clear, the system might even become unworkable. Study results show that the increased costs of compliance may not be as relevant in affecting net benefits to society as the regulatory delays.

Argentina - Socioeconomic assessment as part of the GM regulatory process

By the end of the 1990s, Argentina had implemented a mandatory SEA as an integral part of the approval procedure for GM crops. The aim of the SEA is to avoid barriers to Argentina's international trade. Decisions on the authorisation of cultivation of GM crops are made by the Secretary of Agriculture, Livestock and Fisheries on the basis of three independent expert opinions (an environmental risk evaluation, a food and feed safety assessment and an analysis of the potential impacts on Argentina's international trade), although they are not binding.

The applicant for the authorisation for release of a GM crop for commercialization has to submit, amongst other things, information on the stage of approval of the event in the main markets. As a first step in the procedure, experts from the Directorate on Agricultural Markets draft a preliminary report which evaluates the stage of approval for production, consumption and import in the main importing countries and the competiveness of Argentina as an exporter for the crop, taking into account the situation of the import markets and other exporters. Potential benefits for farmers, consumers, other actors in the food and feed chain and, if applicable, impacts on the agro-ecosystems are also taken into account.

Stakeholders are informed of the conclusions of the report in a meeting and their comments are taken into account for the final expert opinion which is submitted to the Secretary.

Unlike the assessments of the environmental risk and food safety, which are the basis for the technical decision on the authorisation, the SEA is the basis for political decisions. From the very beginning, Argentina's decisions reflected the state of play in the EU (so-called "mirror policy"). In the last few years, and especially in the framework on decisions on soybean events, approvals in China and India were also taken into account. More recently, decisions made in Brazil (as a main competitor) were followed too, although still informally.

A special feature of the SEA is that its conclusions change over time (in contrast to the conclusions of the environmental risk and food safety assessments). An initially unfavourable opinion becomes favourable once trade restrictions are removed (the event has been approved in the importing country). In this way the SEA delays the final decision, usually by a year or two, as the authorisation process in Argentina (without the additional step of a SEA) is generally faster than in the importing countries.

Discussion:

Complementary to the presentations on SEAs in the framework of the CPB and the GM regulatory system in Argentina, experts from The Netherlands and France presented the efforts of their countries in the field. In The Netherlands, experts evaluated literature results on the sustainability of GMO cultivation (compared with conventional crops) applying selected indicators. The study serves to provide information to the Dutch Parliament and, as a follow-up, a workshop is planned for the beginning of 2012. In France, it was decided to introduce a second chamber in the High Council for Biotechnolgy (HCB). In addition to the existing scientific committee (responsible for the biosafety assessment), a socioeconomic committee was established. The task of this socioeconomic committee is to deliver opinions directed at the French government (non-binding) on specific issues.

The experts discussed the trade-off between the benefits of the introduction of a SEA into the approval procedure of a new technology (e.g. GM crops) and its potential negative impacts for innovation. The experts participating in the workshop argued that the inclusion of a robust SEA, in addition to strict science-based safety assessments, could make regulatory decision-making on cultivation more objective and transparent. The EC has made a legislative proposal to the EP and to the Council with the aim of increasing the possibility for the Member States to restrict or prohibit the cultivation of authorised GMOs in their territory based on grounds other than adverse effects to health or environment (see chapter 3.2).

Prospects and conclusions:

Session 4 provided useful information on decisions which have to be taken when introducing SEAs into the GMO regulatory system (e.g. voluntary vs. mandatory SEAs, *ex ante* vs. *ex post* assessment, scope of the SEA). However, the chosen approach will depend on the context (e.g. a SEA focusing on trade barriers is only relevant for an exporting country such as Argentina) and has to be developed on a case-by-case basis, choosing a suitable methodology (see sessions 1-3). Useful information could be obtained by assessing the regulatory process in different countries from the cost/benefit perspective.

4.5 Session 5: Economic compensation, liability issues and institutional framework influencing adoption of GM crops

Presentations:

Liability, compensation, redress in case of admixture: legal issues	Bernhard A. Koch, University of Innsbruck, Austria
Innovation and liability in biotechnology transnational and comparative perspectives	Stuart J. Smyth, University of Saskatchewan, Canada,
Institutional/political factors that influence adoption and profitability of GM crops in South Africa	Marnus Gouse, University of Pretoria, South Africa

Main topics presented:

Session 5 was dedicated to the legal implications of the mixture of GM and non-GM crops and policy and the institutional framework influencing the adoption of GM crops.

Liability in biotechnology - Europe

Even with well-designed policies and regulations, unwanted harmful consequences of GMO cultivation can affect others' assets (e.g. through adventitious admixture in the agricultural supply chain) and, in order to compensate the victims, liability problems have to be solved. There are different mechanisms in place to deal with liability issues, regulation (liability/tort law) and market place liability.

In Europe, regulation is the common approach with tort law being a cornerstone. However, in spite of common fundamental values, tort law requirements vary substantially throughout Europe, leading to variations in the way potential claims would be handled and resolved. Even the notion of "damage" differs from country to country. Not all jurisdictions are prepared to compensate so-called "pure economic loss", such as the loss of value of a crop/product if, due to the presence of GM traces, it commands lower prices or cannot be marketed at all. The sort of loss recognized, the thresholds for compensating farm losses, the likelihood of causation which has to be proven and the required standard of care differ from country to country. Moreover, tort law overlaps with other regulations such as good agricultural practice, coexistence rules and national policies.

Insurance schemes can be introduced in order to distribute the burden of liability for farmers cultivating GM crops between those contributing through the payment of premiums. Insurers may handle claims more efficiently than courts. However, due to a lack of data for risk assessment and the remaining uncertainties in tort law, insurers are still reluctant to offer products.

Compensation funds established with contributions from farmers cultivating GMO crops and/or from government revenue could substitute where insurance schemes are absent. However, these funds would face the same problems as insurers, such as unpredictable developments and difficulties in calculating the risk.

Some EU Member States have already set up compensation funds, e.g. Denmark and Portugal. In Denmark farmers pay a statutory fee per hectare cultivated with GM crops, and the State serves as a short-time financier when losses exceed the limits of the fund. The fund only covers economic loss resulting from actual GMO presence in non-GM crops (e.g. not from environmental damage). However, in the absence of GM crop cultivation the relevance of the scheme is of a purely theoretical nature. Portuguese farmers pay EUR 4 per packet of seeds ("seed tax"), the state does not contribute and the fund only covers accidental economic loss resulting from actual GMO presence in non-GM crops.

Liability in biotechnology – North America

In the USA and Canada, coexistence or segregation of GM crops and non-GM crops is not specifically regulated. Therefore, civil liability applies in the context of GM crop cultivation and liability issues are solved between private parties (marketplace liability). In the event of admixture, the product development company may be held responsible and obliged to pay compensation.

Three court cases were presented in the workshop. Two court cases in the USA concerned the commingling of unapproved GMOs with commercial agricultural crops. StarLink maize had received a so-called "split approval" for feed use (but was not yet approved for food uses) and was supposed to be controlled through an identity preservation system. Despite this, StarLink maize was detected in food products in 2000 and in the ensuing court case, plaintiffs who could prove that their crop, product or market had been negatively impacted by StarLink maize, joined a class action lawsuit. The developer settled out of court by providing USD 110 million in compensation.

In 2006, trace amounts of an unapproved GM rice event (LL601 rice) were found in US exports to the EU. More than 1,000 lawsuits were launched against the biotech company developing the event. The US rice industry lost the EU market for years after this incident and the biotechnology company recently offered USD 750 million in compensation to the rice producers concerned.

In Canada, the Saskatchewan Organic Directorate (SOD) launched a lawsuit in 2001 claiming that organic farmers had suffered fiscal damage from the commercialisation of GM canola, however the lawsuit was rejected by the court.

Institutional and political factors – South Africa

Factors which influence the adoption and profitability of GM crops, such as institutional and political factors, were discussed on the basis of studies from South Africa. The situation in South Africa is characterised by a dualistic agricultural sector. On the one side, large-scale farmers produce the bulk of crops and ensure employment and, to a large degree, national food security, but receive no direct support from the government. On the other side, previously disadvantaged small-scale farmers, the vast majority of whom are subsistence farmers, receive government support to develop infrastructure, skills and markets. Therefore, the South African government has to meet the challenge to develop policies which support both groups of farmers.

Three examples of how institutional and political factors influence adoption of GM crops were discussed: building on a strong scientific history, South Africa implemented their GMO Act (1997) in 1999, constituting a biosafety regulatory authority. The South African Government views biotechnology as a strategic industry to support economic growth. The regulatory authority and the Government-funded Public Understanding of Biotechnology program have created an environment facilitating science-based and balanced considerations and regulation of GM crop cultivation.

The Makhathini Flats Bt cotton experience illustrates the importance of institutional factors in the adoption of GM crops by smallholder farmers. Bt cotton was introduced in 1997 in this region and by 2001 90% of the cotton farmers cultivated Bt cotton. Though adopting farmers benefitted substantially from higher yields and savings on insecticides the rapid adoption rate was largely down to the institutional arrangement with one geographically isolated cotton gin supplying credit and extension services to contract farmers. However, due to institutional failure (ginnery competition and low prices) exacerbated by droughts and floods the cotton cultivation system collapsed in 2002. This example showed that GM crops, like conventional crops, cannot be produced profitably and sustainably without functioning markets and institutional support.

As a third example, the limited adoption of GM maize by smallholder maize farmers was contrasted with the high level of adoption by large-scale commercial farmers. Production and marketing-side limiting factors caused by institutional and political reasons, as well as maize production motivations, were discussed and shown to influence farmers' GM maize adoption decisions.

Discussion:

Experts noted that the two court cases in the USA involved non-approved events and therefore the outcome was not relevant for the question of how courts would decide in the case of adventitious presence of approved GMOs in crops from organic or conventional farming and asked if such examples already exist. Participants were aware of cases where organic farmers in Europe (Spain) claimed damages from GM cultivation. As these cases were (presumably) all settled out of court no information on the outcomes is publicly known.

Participants in the workshop showed interest in how compensation funds (e.g. in Denmark and Portugal) would function in practice. The actual applicability is unknown since there is no record of practical experiences or relevant court cases in Europe. Due to the small number of producers of GM crops in Europe the collected funds might not be sufficient to pay compensation for liability cases unless the State (as in the case of Denmark) or the seed producer (as in the case of Portugal) steps in. The uncertainty created by liability problems and the "compensation fund" may prevent farmers from adopting GM crops. However, experts did not come to an agreement concerning the importance of these factors for farmers' decisions.

It was noted by experts that further private mechanisms exist (in addition to what was mentioned in presentations) to deal with liability issues. Contractual arrangements between biotech companies and farmers may include compensation schemes for the adventitious presence of GMOs in other crops. Additionally, companies frequently find pragmatic solutions for liability issues (out of court) in order to secure their market share. Strong players in the supply chain (e.g. supermarket chains) may receive compensation on the basis of their market power (and independent of court cases).

Concerning the presented case studies from South Africa, it was noted by an expert that the situation in South Africa is characteristic of all sub-Saharan countries. Policy and institutional factors, such as a functioning seed supply system or stability in the availability of credits, are crucial to enable farmers in this region to adopt technologies such as GM crops. This presumably also applies to other countries (e.g. India and China) and studies should be carried out. With regard to the situation in the EU, experts stressed the importance of policy approaches which allow science-based decisions in order not to hamper innovation.

Prospects:

Experts agreed that institutional and policy approaches and liability issues are important factors for reaching decisions on the adoption of GM cultivation and that detrimental developments can hamper innovation. Comprehensive studies on liability approaches exist for Europe and North America whereas currently little is known on the actual impact of liability issues on farmers' decisions concerning GM crop adoption. Moreover, as long as no case is brought to court the extent of the compensations remains hypothetical. Information gaps could be closed by including liability issues as a parameter to be evaluated in farm-level, sector-level and coexistence studies (see sessions 1-3). A methodology for the evaluation of the impact of policy and institutional factors on adoption and profitability of GM crops has been developed. It would be of interest to also conduct such studies in other developing (e.g. India and China) and developed countries (e.g. Europe) where respective data are currently missing.

4.6 *Session 6: Research on consumers attitudes and direct/indirect impacts of GM crops on consumers including health*

Presentations:

Reviewing science behind consumer attitudes, willingness to pay	Matty Demont, African Rice Centre, Saint Louis, Senegal
Transgenic crops in the context of global health	Felicia Wu, University of Pittsburgh, USA
Consumer reactions/choice (findings of the project CONSUMERCHOICE)	Vivian Moses, King's College, London, UK

Main topics presented:

Session 6 addresses the issue of consumer attitudes towards GM crops, which is of significant importance for the adoption of GM crops: even when GM crops perform better than conventional crops, they will not be cultivated if consumers are not willing to buy them. One presentation reviewed the theory behind studies on consumer choice and a second presentation gave more empirical insights into this issue. In addition, a third presentation dealt with the health benefits associated with GM crops.

Measuring the preference of consumers

Many researchers have set out studies to measure the preference of consumers regarding GM or non-GM food products (estimated by the ***Willingness To Pay - WTP***), and several reviews of these studies are available. Two main types of methodologies to elicit consumers' valuation of GM products can be distinguished, depending on whether the valuation process is hypothetical or not. In the case of the first method (such as contingent valuation), the preferences of consumers are stated, i.e. they are elicited in a hypothetical framework, for instance with questions about purchase intentions. This method is generally easier to implement than the non-hypothetical one, as it allows quick collection of data at low cost (which is specifically relevant in developing countries). However, experience showed that when consumers are asked (theoretically) how much they are willing to pay for non-GM food products, they generally state higher prices than in real (or experimental) purchase situations. This so-called 'hypothetical bias' may lead to a 2.6 times over valuation of WTP for non-GM food, according to a 2005 estimate.

The second method, namely "revealed preference", was developed amongst other reasons in order to overcome drawbacks associated with the stated preference method. Its main purpose is to elicit consumers' WTP for non-GM products by positioning them in real purchasing situations. For instance, in experimental auctions, participants are encouraged to bid for real products with real money, within a set of rules that provide incentives to faithfully reveal the valuation of consumers for GM or non-GM products for sale. Experimental auctions are especially useful in situations where no market for the assessed GM food products exists.

Results of studies on consumer preference for GM / non-GM food products

Two main findings emerge from the growing body of literature on consumers' attitudes towards GM food products: (1) consumers in developed countries have a preference for non-GM food, especially in Europe, whereas (2) in developing countries (e.g. China) they are more inclined to buy GM food than in industrial countries, even leading in some cases to a price premium for these products. The first finding was confirmed by a recent meta-analysis. However, the second one was questioned by experts who suggested that hypothetical bias (in these countries most studies tend to rely on hypothetical methods and purchase intention questions rather than on real life situations) may have led to an overvaluation of the preferences of consumers.

A recent two-year study in the EU (ConsumerChoice, funded by EU Framework Programme for Research) evaluated whether the actual purchase behaviour of consumers corresponds to the answers they gave when asked whether they would or would not buy GM food products. In the main survey, conducted in Spain, The Netherlands, the Czech Republic, Poland and the UK, all products purchased by a panel of consumers in selected supermarkets where GM cooking oil and other products were available during a given period of time were recorded through barcode scanning. Eventually, the data collected were compared with the statements of the very same (albeit anonymous) consumers regarding their willingness to buy GM food products. Additional surveys studied the purchase behaviour concerning the selection of "GM-free" milk in Germany, and of the awareness and choices made by Polish citizens living in the US and by UK residents who had travelled to North America, where GM food products are widespread but unlabelled. Eventually, the researchers surveyed which GM products were available for purchase, and whether they remain in stores over time, assuming that shelf space is very valuable and shops do not continue to stock products which do not sell. Yet GM products have remained on offer for years in those five countries listed above.

Depending on the circumstances (type of survey, sample of consumers) and the European country, the results of this study varied but not greatly. Two general conclusions could be drawn. Firstly, the actual purchase behaviour of consumers regarding GM food products does not correspond to their stated attitude when asked on the subject; and secondly, when GM food products are available on the shelves, consumers are generally willing to buy them.

Potential health benefits for consumers of GM crops

Consumers usually do not associate consumption of GM products with health benefits. However, studies show some evidence that first generation GM crops may provide health benefits, even if this was not breeders' intention.

Currently cultivated GM crops may increase labour productivity and therefore either slacken the constraints of workforces in regions where it is scarce (e.g. in areas where HIV is highly prevalent) or allow workers to engage in other food production activities that will help diversify their diet. Secondly, producers may also benefit from the reduced amount of insecticides spread on the fields (in the case of IR crops), or from the lower toxicity of herbicides used (in the case of HT crops).

There is also an important but often unrecognized health benefit for consumers associated with Bt crops. Multiple field studies have shown that concentrations of certain mycotoxins are significantly lower in Bt maize than in its conventional isoline. As the crystal (Cry) proteins that are synthesised by the plant thanks to the insertion of the Bt gene result in reduced insect damage, there is also a reduction in the levels of toxin-producing fungi colonizing the maize ears. These mycotoxins can cause adverse health effects in humans. Therefore, their reduction results in improved health outcomes, and consumers, especially in developing countries where mycotoxin contamination is higher (because of conducive climate and/or less stringent food safety regulation and enforcement), could benefit from the adoption of Bt maize.

Discussion:

During the discussion participants raised methodological issues on how to obtain representative samples, focusing on shoppers rather than on consumers in general. Some biases can be overcome by using econometrical methods; however, experts noted that wherever GM foods are available for sale, better results would be obtained by performing surveys directly in the marketplace. But the latter also have some limitations and therefore it might be useful to carry out experimental studies to elicit consumer preferences.

Participants also wondered why according to poll surveys consumers reject GM food products, whereas studies show that consumers do buy them when they are available on the shelves. While some experts stated that providing more information to consumers would increase their understanding regarding safety and GM technology, and thus their acceptance of GM food, others argued that they would expect the government to provide an environment allowing all stakeholders to operate in the market. Participants stated that consumers are not a homogenous group, with some of them rejecting GM food products, others being neutral and the remainder being interested in buying GM food. Generally, the level of opposition to GM food rises with the higher income and better education of consumers.

Prospects and conclusions:

As for the socio-economic assessment of GM crops at farm level, experts have to focus on the choice of a suitable methodology and address methodological limitations when studying consumers' preferences concerning GM or non-GM food and WTP. Study design is especially challenging in countries such as EU Member States where few food products labelled as GM are available. In the absence of GM food products, surveys on the marketplace (*ex post*) are not possible. In this case, in order to avoid hypothetical bias, preference should be given to methods where consumers have to make real purchase decisions (such as experimental auctions for instance) over methods where preferences of consumers are only stated.

4.7 *Session 7: Looking forward: New GM crops in the pipeline and their possible economic and social impacts*

Presentations:

Global pipeline of GM crops by 2015	Emilio Rodriguez Cerezo, European Commission, JRC-IPTS, Spain
Predicting "ex ante" the economic impact of a new GM crop: the case of CRW-resistant maize in Europe	Koen Dillen, European Commission, JRC-IPTS, Spain
Closing talk: the future of GM rice and the possible social and economic impacts in Asia	Gerard Barry, International Rice Research Institute, Philippines

Main topics presented:

The final session reviewed new GM crops which are expected to be released in the coming years and the implications for socio-economic impact assessments.

The pipeline of GM crops with a special focus on Asia

The global pipeline for GM crops is active and is expanding: up to 124 GM events are expected to be commercially available by 2015, compared to some 40 GM events released so far. Currently, the four major GM crops (maize, soybeans, cotton and rapeseed) represent around 80% of the total number of commercialized GM events, whereas by 2015 this figure will fall to around 60%. New varieties for some of the most important crops for global agriculture, such as rice (no GM rice is yet commercially used) or potatoes, will eventually be included in the list of available GM varieties. Also for "smaller" (but no less relevant) crops, such as tomato, eggplant, papaya, alfalfa, or cabbage, new genetically engineered varieties are expected to be available by 2015. Thus, there will be a slight but significant diversification in terms of genetically modified species, but also in terms of traits. Even if the two main existing ones (herbicide tolerance and insect resistance) will still dominate by 2015, other agronomic traits are also expected. These traits (some new) include resistance to viruses, improved resistance to diseases and tolerance to abiotic stresses (such as drought or high salinity). The first 'second generation' GM crops are also expected to be commercially available by 2015. These crops will specifically address the needs of consumers through, for instance, improved fatty acid profile or higher content in beta carotene. Some crops with events designed to meet the needs of the industrial sector (including the biofuel industry) will also be available.

Major changes are expected in the years to come concerning the region of origin of GM events. Indeed, while in 2008 three out of four commercialized GM events were still developed by North American or European companies, the coming years will see the emergence of technology providers from Asia as a major source of GM events. This region will be especially active by putting on the market the first GM rice varieties, even if the release of some of the GM rice events in the pipeline a few years ago has been delayed or even cancelled. Most of the rice events close to commercialization are insect resistant varieties, in addition to the biofortified rice called Golden Rice.

However, both in India and China, governments do not consistently support the release of GM rice and other GM food crops. In China, concerns about possible low consumer acceptance of GM food and recently tightened controls on Chinese rice exports to the EU appear to have slowed down the approval process for GM rice. In India, various new regulations regarding biotechnology are waiting to be promulgated. Nevertheless, in both countries the dynamic of the research pipeline seems unaffected by the uncertainties of governments. Recently, a Bt rice event (Bt63) received a biosafety certificate from the Chinese regulatory agency, but variety registration is still delayed. Numerous field trials are conducted in China for crops with different traits, including insect resistance, herbicide tolerance, drought and salt tolerance, nitrogen use efficiency, and grain quality, many of them developed by public national centres.

In India, the central government continues to authorise new field trials, but they are subject to the final approval of the local state governments. Nevertheless, late stages of regulatory trials for a Bt rice developed by a private company have recently been conducted, and other trials are following. In the case of Golden Rice, an event genetically modified to express genes that lead to the accumulation of beta carotene in the rice grain – beta carotene is a precursor of vitamin A – the development is already quite advanced, and a regulatory dossier could be delivered to the authority in the Philippines by 2013. Indeed, among Asian countries, the Philippines and Indonesia might be the ones releasing the first commercial GM rice in the next years.

New GM events and implications for socio-economic impact assessment

The new traits incorporated by the GM crops in the pipeline would require new socio-economic indicators to assess their impact. Improvement in crop quality may generate nutritional or health benefits for consumers, and thus may change their attitude toward GM crops.

New evaluation methods and new economic indictors are required to measure the direct nutritional or health effects of these crops with new traits for nutritional improvement, and to compare the cost effectiveness of the use of these crops with alternative public health measures.

Actually, some *ex ante* assessments of the impacts of new GM crops are already available. In the case of Golden Rice, recent studies estimated (using a Disability Adjusted Life Years [DALY] indicator) the reduction in morbidity and mortality potentially generated by the introduction of this crop. Results show a significant beneficial health impact, at a lower cost when compared with alternative public measures. *Ex ante* studies for Bt rice conducted in China estimated huge internal gains for rice production, even when considering the potential loss of export markets.

In the case of the European Union, a recent *ex ante* study simulated the level of adoption and the economic impacts of the introduction of a GM maize designed to control the Western Corn Rootworm, a pest that arrived in Central Europe in the 1990s. This trait is available in the USA but not yet in the European Union. Different options for crop protection were compared (crop rotation, chemical protection or GM maize), and the high heterogeneity within farmers in the region was taken into account in the model. The bio-economic simulations predict that in Hungary, for 69% of the farmers in a land constraint situation, the crop rotation option will ensure a higher income than GM maize, whereas 78% of maize monoculture farmers would be better off relying on GM maize than on insecticide applications. Results from other Central European countries indicate that, in general terms, the introduction of this new GM maize in Central Europe would significantly reduce the quantity of soil insecticides used, and offer a better protection against the economic loss due to Western Corn Rootworm by increasing the available crop protection toolbox.

Discussion:

Experts discussed the accuracy of the commercial pipeline of GMOs. Big discrepancies were noted in the past between the announced and actual dates of release for certain GM events. However, it was also noted that, in some cases, new GM crops had been available in a shorter time than expected. In sum, commercial pipelines are not very reliable when dealing with longer term, and should instead be focused on events in the later stages of R&D. But with time, experts expect an increase in the probability of developed events eventually being commercially released, as more public or public-related actors, who have a more accurate view of the needs of the market, will be involved in the research funding.

The experts also discussed the impact of the evolution of world agricultural markets on the development and trade of GM crops, with a special reference to the recent 'food crisis', i.e. the 2007-08 rise in food prices. It was noted that in some Asian countries, such as Bangladesh, the increase in food prices concentrated the consumption of the poorest households on rice, dramatically reducing their dietary diversification. Therefore this situation reduced the intake of higher nutrient foods, exacerbating micronutrient deficiency troubles, especially among women, and thus made the biofortified crops more relevant. Additionally, in sub-Saharan Africa, the so-called food crisis or some acute drought conditions have made a number of poor countries more tolerant of importing GM white maize and incorporating it into their food system. This might eventually change attitudes there towards GM crops.

Prospects:

This session brought back to mind the fact that the pipeline for GM events is really active and that the number of crops and traits developed with the help of biotechnology will strongly increase in the coming years. Experts agreed that the potential of this technology is huge, even if it may still take some time to get very new traits on the market. As some of the new GM events will show other characteristics beyond just agronomic benefits, new indicators for socio-economic assessment will be required. As a consequence, there will be a need for new surveys and data collection.

Annex 1: List of Participants

INTERNATIONAL WORKSHOP ON SOCIO-ECONOMIC IMPACTS OF GENETICALLY MODIFIED (GM) CROPS (CO-ORGANISED BY JRC-IPTS AND FAO)

LIST OF PARTICIPANTS

23-24 November 2011
European Commission
Joint Research Centre
Institute for Prospective Technological Studies

Venue: Edificio Expo - c/ Inca Garcilsaso 3 - 1st Floor, Room 30A - Seville, Spain

European Commission			
BOCK	Anne-Katrin	JRC, Unit Programming, Delivery and Modelling	EU
BREGEON	Thomas	Directorate General Health and Consumers (DG SANCO). Unit Biotechnology	EU
DE BACKER	Walter	Directorate General Agriculture and Rural Development (DG AGRI). Unit Cross-compliance, food and feed legislation, POSEI	EU
DELINCÉ	Jacques	JRC, IPTS, Unit Agriculture and Life Sciences in the Economy	EU
DILLEN	Koen	JRC, IPTS, Unit Agriculture and Life Sciences in the Economy	EU
LUSSER	Maria	JRC, IPTS, Unit Agriculture and Life Sciences in the Economy	EU
PARISI	Claudia	JRC, IPTS, Unit Agriculture and Life Sciences in the Economy	EU
PLAN	Damien	JRC, IHCP, Unit Molecular biology and genomics	EU
RODRÍGUEZ CEREZO	Emilio	JRC, IPTS, Unit Agriculture and Life Sciences in the Economy	EU
TILLIE	Pascal	JRC, IPTS, Unit Agriculture and Life Sciences in the Economy	EU
Food and Agriculture Organization of the United Nations (FAO)			
RANEY	Terri	FAO	
Member States Experts			
ANDORKÓ	Rita	Ministry of Rural Development	Hungary
BATIC	Martin	Ministry of the Environment and Spatial Planning	Slovenia
CRIJNS	Bart	Ministry of Economic, Agriculture, Innovation	The Netherlands
CZARNAK-KŁOS	Marta	Ministry of Agriculture and Rural Development	Poland
DEL RIO	Omar	Ministry of Environment, Rural and Marine Affairs	Spain

FLANDROY	Lucette	Federal public Service Health, Food Chain Safety & Environment	Belgium
IVANUS	Adriana	Ministry of Environment and Forests	Romania
KNORPP	Carina	Ministry for Rural Affairs	Sweden
MANNONEN	Leena	Ministry of Agriculture and Forestry	Finland
RÉMONDET	Martin	Haut Conseil des biotechnologies	France
O'NEILL	John	Department of Environment	Ireland
ORLOVA	Olga	Permanent Representation of Latvia to the EU	Latvia
PIVORIENE	Odeta	Ministry of Environment	Lithuania
PRINZ	Carlo	Federal Ministry of food, Agriculture and Consumer	Germany
ROWE	Michael	Department for Environment, Food and Rural Affairs	United Kingdom
SPATARO	Giorgia	Ministero delle Politiche Agricole Alimentari e Forestali	Italy
STRATILOVA	Zuzana	Ministry of Agriculture	Czech Republic
Speakers			
BARRY	Gerard	International Rice Research Institute	Philippines
DEMONT	Matty	Africa Rice Center	Senegal
FALCK-ZEPEDA	Jose	International Food Policy Research Inst (IFPRI)	United States
GOUSE	Marnus	University of Pretoria	South Africa
HUFFMAN	Wallace	Iowa State University	United States
KALAITZANDONAKES	Nicholas	University of Missouri	United States
KOCH	Bernhard	University of Innsbruck	Austria
MENRAD	Klaus	University Weihenstephan	Germany
MOSES	Vivian	King's College London	United Kingdom
PRAY	Carl	Rutgers University	United States
QAIM	Matin	Georg-August University	Germany
RIESGO	Laura	Pablo de Olavide University	Spain
SMALE	Melinda	AFRE, Michigan State University	United States
SMYTH	Stuart	University of Saskatchewan	Canada
VICIEN	Carmen	Universidad de Buenos Aires	Argentina
WESSELER	Justus	Technische Universitaet Muenchen	Germany
WU	Felicia	University of Pittsburgh	United States
ZILBERMAN	David	UC Berkeley	United States
ZIMMER	Christoph	Verband Lebensmittel ohne Gentechnik e.V.	Germany

Annex 2 Agenda

INTERNATIONAL WORKSHOP ON SOCIO-ECONOMIC IMPACTS OF GENETICALLY MODIFIED (GM) CROPS (CO-ORGANISED BY JRC-IPTS AND FAO)

AGENDA

23-24 November 2011
European Commission
Joint Research Centre
Institute for Prospective Technological Studies

Venue: Edificio Expo - c/ Inca Garcilsaso 3 - 1st Floor, Room 30A - Seville, Spain

23 November 2011		
Time	**Programme items**	**Speaker**
OPENING **CHAIR: Emilio Rodriguez Cerezo, European Commission, JRC-IPTS**		
9:00-9:15	Welcome	
9:15-9:45	Opening& Objectives of the workshop	Emilio Rodriguez Cerezo, European Commission, JRC-IPTS Terri Raney, FAO Thomas Bregeon, European Commission, DG SANCO
Session 1: Adoption of GM crop varieties and socio-economic impacts on farmers (including impacts on input uses, agricultural practices, etc.) **CHAIR: Terri Raney, FAO**		
9:45-10:20	Global status of GM crop adoption and review of impacts on developing world's farmers	Matin Qaim, Universität Göttingen, Germany
10:20-10:45	Adoption and impacts at farm level in the USA	Wallace Huffman, Iowa State university, USA
10:45-11:00	The case of Bt maize in the EU	Emilio Rodriguez Cerezo, European Commission, JRC-IPTS
11:00-11:30	Coffee break	
11:30-11:55	Challenges in measuring the economic impacts of biotech crops on farms in developing agriculture	Melinda Smale, Michigan State University USA
11:55-12:25	Discussion	
Session 2: Aggregated and global impacts of GM technology in agriculture **CHAIR: Emilio Rodriguez Cerezo, European Commission, JRC-IPTS**		
12:25-12:50	Welfare creation and distribution	Carl Pray, Rutgers University, New Brunswick, USA
12:50-13:15	Impacts on global productivity and world food prices	David Zilberman, University of California, Berkeley, USA
13:15-13:45	Discussion	

Continuation 23 November 2011		
Time	**Programme items**	**Speaker**
13:45-14:45	Lunch break	
Session 3: Economics of segregation/coexistence of supply chains **CHAIR: Emilio Rodriguez Cerezo, European Commission, JRC-IPTS**		
14:45-15:00	Case studies of supply chain analysis and segregation costs in the EU	Klaus Menrad, University Weihenstephan, Straubing, Germany
15:00-15:25	Coexistence of GM and non-GM supply chains in the EU: policy framework and economic aspects	Justus Wesseler, Technical University Munich, Germany
15:25-15:40	EU coexistence policies may shape future adoption of GM technology by EU farmers	Francisco Areal, Laura Riesgo* and Emilio Rodriguez Cerezo European Commission, JRC-IPTS
15:40-15:55	Managing GM free label	Christoph Zimmer, VLOG, Berlin, Germany
15:55-16:20	The global agricultural supply chain: feasibility, costs and opportunities of coexistence of GM and non-GM commodities	Nicholas Kalaitzandonakes, Univ. Missouri, USA
16:20-16:50	Discussion	
16:50-17:20	Coffee break	
Session 4: Socio economic impacts of GM crops: examples of use in decision-making **CHAIR: Terri Raney, FAO**		
17:20-17:45	Socio economic considerations of GM crops in the context of the Cartagena Protocol of Biosafety- CBD	José Falck-Zepeda, IFPRI, Washington, USA
17:45-18:10	Socioeconomic assessment - a requirement for authorisation for cultivation of GM crops in Argentina	Carmen Vicién, University of Buenos Aires, Argentina
18:10-18:30	Discussion	
21:00-23:00	Dinner	

24 November 2011		
Time	**Programme items**	**Speaker**
Session 5: Legal issues, institutional frameworks influencing adoption of GM crops **CHAIR: Maria Lusser, European Commission, JRC-IPTS**		
9:00-9:25	Liability, compensation, redress in case of admixture: legal issues	Bernhard A. Koch, University of Innsbruck, Austria
9:25-9:50	Innovation and liability in biotechnology: transnational and comparative perspectives	Stuart J. Smyth, University of Saskatchewan, Canada,
9:50-10:15	Institutional/political factors that influence adoption and profitability of GM crops in South Africa	Marnus Gouse, University of Pretoria, South Africa
10:15-10:45	Discussion	
10:45-11:15	Coffee break	
Session 6: Research on consumers attitudes, direct/indirect impacts of GM crops on consumers including health issues **CHAIR: Thomas Bregeon, European Commission, DG SANCO**		
11:15-11:40	Reviewing science behind consumer attitudes, willingness to pay	Matty Demont, African Rice Centre, Saint Louis, Senegal
11:40-12:05	Transgenic crops in the context of global health	Felicia Wu, University of Pittsburgh, USA
12:05-12:30	Consumer reactions/choice (findings of the project CONSUMERCHOICE)	Vivian Moses, King's College, London, UK
12:30-13:00	Discussion	
13:00-14:00	Lunch break	
Session 7: Looking forward: New GM crops in the pipeline and their possible economic and social impacts **CHAIR: Terri Raney, FAO (presentations)** **Emilio Rodriguez Cerezo, JRC-IPTS (discussion and closing)**		
14:00-14:15	Global Pipeline of GM crops by 2015	Emilio Rodriguez Cerezo, JRC-IPTS
14:15-14:30	Predicting "ex ante" the economic impact of a new GM crop: the case of CRW-resistant maize in Europe	Koen Dillen, European Commission, JRC-IPTS
14:30-14:55	Closing talk: the future of GM rice and the possible social and economic impacts in Asia	Gerard Barry, International Rice Research Institute, Philippines
14:55-15:15	Discussion	
15:15-15:25	What comes next?	Thomas Bregeon, European Commission, DG SANCO
15:25-15:30	Closing	

Annex 3: Papers

Global status of GM crop adoption and review of impacts on developing world's farmers

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Introduction

The global area under genetically modified (GM) crops grew from 1.7 million ha in 1996 to 148 million ha in 2010. Today, over 15 million farmers worldwide grow GM crops in 29 countries, including 19 developing countries (James 2010). This rapid spread has been accompanied by an intense public debate. While some see great potential in GM crops to raise agricultural productivity and contribute to sustainable development, others emphasize the potential environmental, health, and social risks. Especially with respect to developing countries, there are concerns that smallholder farmers would not be able to benefit. While emotional public controversies continue, there is a growing body of literature providing empirical evidence on impacts of GM crops in different countries. Here, we present an overview of global GM crop adoption, and review recent impact studies with a focus on the developing world.

Global status of GM crop adoption

The commercial adoption of GM crops began in the mid-1990s. Since then, the technology has spread rapidly around the world. In 2010, GM crops were already grown on 148 million ha in 29 countries. The countries with the biggest GM crop area shares are the US (45%), Brazil (17%), Argentina (15%), India (6%), Canada (6%), and China (2.5%) (James 2010). Among the countries of the European Union (EU) only Spain grows GM crops on a significant scale. In other EU countries, GM crop areas are negligible, largely due to public acceptance problems.

In spite of the widespread international use of GM crops, the portfolio of commercialized crop-trait combinations is still quite limited. Up till now, only a few first-generation GM crops have been commercialized. The dominant technology is herbicide tolerance (HT) in soybeans, which made up 50% of the global GM crop area in 2010. HT soybeans are mostly grown in the US, Argentina, Brazil, and other South American countries. GM maize is the second-most dominant crop, covering 31% of the global GM area in 2010. It involves HT and insect resistance, partly as separate and partly also as stacked technologies. Insect resistance is based on different genes from *Bacillus thuringiensis* (Bt). HT and stacked HT/Bt maize is cultivated primarily in North and South America and in South Africa; Bt maize is also grown in a number of other countries, including Spain and the Philippines.

Other GM crops with significant area shares include cotton and canola. Bt cotton is particularly relevant in developing countries. In 2010, India had the largest Bt cotton area with 9.4 million ha, followed by China with 3.5 million ha. South Africa, Argentina, Mexico, and a few other countries use this technology as well. In the US, Bt and HT cotton are employed, partly as stacked technologies. HT canola is mostly grown in Canada and the US. There are also a few other GM crops that have been approved in individual countries, so far only covering relatively small areas. Those include HT alfalfa and sugarbeet as well as virus-resistant papaya, among others.

Impacts of HT crops

HT adopting farmers benefit in terms of lower herbicide expenditures. Total herbicide quantities applied were reduced in some situations, but not in others. In Argentina, herbicide quantities were even increased significantly. This is largely due to the fact that herbicide sprays were substituted for tillage. The share of soybean farmers using no-till has increased significantly since the introduction of HT technology. In terms of yields, there is no significant difference between HT and conventional crops in most cases. Only in some regions, where certain weeds were difficult to control with selective herbicides, the adoption of HT and the switch to broad spectrum herbicides resulted in better weed control and higher crop yields.

Overall, HT technology reduces the cost of production through lower expenditures for herbicides, labor, machinery, and fuel. Yet, the innovating companies charge a technology fee on seeds, which varies between crops and countries. Several studies for HT crops in the US and Canada showed that the fee was in a similar magnitude as the cost reduction in agricultural production, so that profit effects for farmers were small. In South American countries, the average profit effects are larger, because – due to weaker intellectual property rights (IPRs) – the technology fee charged on seeds is lower. In Argentina, the average profit gain through HT soybean adoption is in a magnitude of USD 23 per ha. The technology is so attractive for farmers that HT is now used on 100% of the Argentine soybean area. In Brazil and other South American countries, adoption rates have also increased rapidly (Qaim 2009).

Impacts of Bt crops

If insect pests are effectively controlled through chemical pesticides, the main effect of switching to Bt crops will be a reduction in insecticide use, as the genetic resistance mechanism substitutes for chemical control agents. However, there are also situations where insect pests are not effectively controlled by chemical means, due to the unavailability of suitable insecticides or other technical, financial, or institutional constraints. In those situations, Bt can help reduce crop damage and thus increase effective yields. Table 1 shows that both insecticide-reducing and yield-increasing effects of Bt crops can be observed internationally.

Profit effects of Bt technologies are also shown in Table 1. In spite of higher prices for seeds, Bt adopting farmers benefit financially. Yet the absolute gains differ remarkably. On average, they are higher for Bt cotton than for Bt maize, and they are also higher in developing than in developed countries. The latter is due to higher pest pressure in the tropics and weaker IPR protection in developing countries.

Especially in China, India, and South Africa, Bt cotton is often grown by small-scale farmers with land areas of less than 5 ha. In South Africa, many smallholders grow Bt white maize as their staple food.

Table 1. Average farm level effects of Bt Crops

Country	Insecticide reduction (%)	Increase in effective yield (%)	Increase in profit (US$/ha)
		Bt cotton	
Argentina	47	33	23
Australia	48	0	66
China	65	24	470
India	41	37	135
Mexico	77	9	295
South Africa	33	22	91
USA	36	10	58
		Bt maize	
Argentina	0	9	20
Philippines	5	34	53
South Africa	10	11	42
Spain	63	6	70
USA	8	5	12

Several studies show that Bt technology advantages for small-scale farmers are in a similar magnitude as for larger-scale producers, in some cases even higher (Qaim 2009). In a study for Bt cotton in India, Subramanian and Qaim (2010) revealed sizeable employment-generating and poverty-reducing effects in the small farm sector, while Kouser and Qaim (2011) showed significant health benefits due to lower exposure to toxic pesticides.

Sustainability of effects

Like any new technology, GM crops tend to impact on ecosystem dynamics. Thus, system adaptation processes may potentially influence technological effectiveness over time. For instance, pest populations may develop resistance to GM pest control mechanisms. In certain locations where HT crops are used extensively, resistance to broad-spectrum herbicides such as glyphosate has been observed in some weed species. Resistance management can be improved through proper crop and technology rotations. For Bt crops, insect pest species may develop resistance. Furthermore, non-Bt target insects (secondary pests) may gain in importance. If this were to happen, the benefits of Bt crops would decrease over time, which could create social problems especially in the small farm sector.

Recent research in India has analyzed the sustainability of Bt cotton impacts based on panel survey data (Krishna and Qaim 2011). Strikingly, Table 2 shows that the beneficial effects of Bt did not decrease but increase over time. Obviously, Bt resistance development and secondary pest outbreaks are not yet problems of practical relevance in India. While long-term effects are still uncertain, these results mitigate the concern that GM crops would soon become ineffective in smallholder environments.

Table 2. Treatment effects of Bt cotton in India (per ha of Bt compared to conventional cotton)

	Insecticide use (kg of active ingredients)	Cotton yield (kg)	Incidence of farmer pesticide poisoning
Bt in 2002-2004	-2.35***	289***	0.10
Bt in 2006-2008	-3.21***	734***	-0.96***

*Sources: Krishna and Qaim (2011), Kathage and Qaim (2011), Kouser and Qaim (2011). Notes: The estimates are based on fixed effects panel regressions with representative survey data collected between 2002 and 2008 in four waves and in four states of central and southern India. Appropriate control variables were included. *** Coefficient estimate is statistically significant at the 1% level.*

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Adoption and impacts at farm level in the USA

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The GM field crop revolution started in the USA in 1996 as the first GM-corn, soybean and cotton varieties became available to farmers. Soybean, corn, and cotton varieties became available with genetically engineered herbicide tolerance (HT), and cotton and corn varieties became available that were engineered for insect resistance (IR) (Fernandez-Cornejo and McBride 2000, NRC 2010). Second generation GM traits of herbicide tolerance and insect resistance became available by 2000 for cotton, and for corn shortly thereafter. Third generation GM corn varieties became available to some farmers in 2010, and Monsanto has an eight transgene variety—three genes for above ground insect resistance, three for below ground insect resistance, and two for herbicide tolerance. IR varieties provide a biological alternative to chemical insecticide applications and provide a reduced pesticide load on the environment and lower risks to human health (NRC 2010). HT soybean, corn, and cotton provide more effective weed control than with earlier herbicides. The key herbicide in this process is *Roundup*, which is environmentally and human health friendly relative to earlier chemical herbicides used for weed control (NRC 2010). In contrast, GM-wheat varieties are not available to farmers. The primary reason is the negative image that GM wheat has in the export market.

The objective of this paper is to review the adoption rates for GM field crops in the USA and examine their impacts on production decisions of farmers in US Midwestern states, which is the leading area in the USA for corn and soybean production and adoption of GM corn and soybean varieties. The impact GM corn and soybean varieties on farmers' production decisions are examined with the aid of an aggregate profit function and the associated input demand and output supply functions, which are fitted to data for eight Midwestern State over 1960-2004. This methodology uses prices of farm outputs (corn, soybean, wheat and livestock) and inputs (capital services, labor, farm energy, agricultural chemicals and other materials) and quasi-fixed factors, including technology indicators for GM seed adoption, to explain farmers' decision on the quantity of outputs to produce and inputs to use. Findings include the following technology effects: A higher GM-soybean and corn adoption rate reduces the demand for all inputs and biases input decisions toward farm chemicals. The shadow value, or increase in profit, from increasing the GM soybean and corn adoption rates is significantly larger than the marginal cost, supporting farmers' decisions to adopt these GM corn and soybean varieties and future high adoption rates of these crops.

GM Field-Crop Introduction and Adoption

In the mid-90s, the science of biotechnology was applied by private seed companies to develop new methods for controlling pests. A recent NRC report (NRC 2010) summarizes the generally favorable environmental effects of these GM crop varieties. When plants are genetically engineered to be herbicide tolerant (HT), e.g., *Roundup Ready*, they survive the application of the herbicide *Roundup* with minimal harm. When farmers plant GM-soybean varieties, this technology replaces more expensive, less effective and more toxic herbicides and hand weeding. Also, farmers have a significant window of opportunity for applying the herbicide and obtaining effective control of weeds (Fernandez-Cornejo 2008). However, when US farmers purchase GM soybeans (cotton and canola), they must sign an agreement with the seed company waving their right to save GM seed for their own use or for sale. HT corn has many of the same advantages, although corn is more competitive against weeds than soybeans, and the herbicide Atrazine can be used on non-GM corn to control broadleaf weeds. However, Atrazine use has contaminated ground water in the Midwest, and consumption of this polluted water can cause health problems.

The grand goal of plant bioengineering, however, was to create biological insect resistance (IR) in plants. For example, one major pest experienced by Midwestern farmers is the European corn borer, which damages stocks and makes the corn plant subject to lodging. *Bacillus thuringiensis* (*Bt*) is a bacteria that occurs naturally in the soil. Several advantages exist for *Bt* corn varieties. First, the level of toxin expressed can be very high, thus delivering a lethal dosage to target insects. Second, the corn plant produces the toxin throughout its life and the toxin is distributed relatively uniformly throughout all plant parts. Hence, *Bt* provides season-long protection against target insects, but has no significant effect on other insects.[1] Third, the toxin expression can be modulated by using tissue-specific promoters, and GM resistance replaces the use of synthetic pesticides in an attempt to kill target insects. Fourth, the *Bt* toxin expressed in the corn plants is not toxic to humans or animals. Although the early *Bt* corn varieties were resistant to the European corn borer, they were also somewhat protective against the corn earworm, the southwestern corn borer and to a lesser extent the cornstalk borer (Fernandez-Cornejo and McBride 2000). Later, *Bt*-corn varieties carried resistance to corn rootworms, which are a pest that reduces and weakens the root structure of corn plants. New evidence shows that farmers planting non-GM corn hybrids are major beneficiaries from other farmers planting *Bt*-corn hybrids because area-wide moth counts have been steadily declining as the *Bt*-corn adoption rate in an area increases. However, some evidence of resistance to GM rootworm control is surfacing.

The first successful GM field-crop varieties were planted in 1996, accounting for 7 percent of the soybean acreage, 4 percent of the corn acreage and for 17 percent of the cotton acreage. Although *Bt*-cotton adoption got off to a fast start in 1996, the HT-cotton adoption rate surpassed the *Bt*-cotton adoption rate by 1998, reflecting the fact that weeds are a persistent problem in cotton, and HT-cotton has experienced higher adoption rates than Bt-cotton through 2010. Although the US adoption rate for HT-soybean varieties was initially lower than for *Bt*-cotton, HT-soybean varieties have experienced very rapid adoption rates over 1997-2007, except for a brief setback over 1999-2000, when new uncertainties about the future market for GM crops in Europe surfaced. However, in 2004, GM soybeans accounted for 85 percent of planted acres in 2004 and 93 percent acres in 2010. The adoption of HT- and IR-corn varieties started more slowly. The GM adoption rate for HT corn declined a little over 1998-2000, and the *Bt* corn adoption rate declined significantly over 1999-2000, deviating from trend by more than 10 percentage points. After 2000, the IR- and HT-corn adoption rates increased slowly until the mid-2000s when the pace peaked up. In 2004, 47 percent of US corn acreage were planted to varieties with one or more input traits. By 2010, this adoption rate had reached 86 percent. In the eight Midwestern US states that are the focus of the empirical analysis of production effects of GM field crops, the adoption rates mirrored those at the US level.

1 Bt produces spores that form the crystal protein insecticide δ-endotoxins. The protein toxin is active against species of the order Lepidoptera, Diptera, Coleoptera, Hymenoptra and nematodes. When these insects ingest toxin laden crystals, chemicals in their digestive track activate the toxin. It inserts into the insect's gut cell-membrane and dissolves it and eventually causes death of the insect.

Production Decisions and Impacts of GM Field Crops

The responsiveness of farms to (expected) prices of outputs and inputs is an important dimension of the structure of Midwestern farm production (see Schuring et al. 2011 for more details). All own-price elasticities are negative for inputs and positive for outputs, except for livestock. The negative own-price effect for livestock may arise as farmers respond to an increase in livestock prices by marketing animals at lighter weights or building breeding-stock inventories. Among the outputs, the own-price elasticity of supply for wheat is largest, 0.79, for corn is moderate, 0.33, and for soybeans is smallest, 0.12. Hence, the elasticity of supply of major crops produced in Midwestern production is substantial. Among inputs, the own-price elasticity of demand for farm chemicals is largest, -0.71, and followed by farm energy, -0.38 and "other materials, -0.27. The other (variable) inputs have somewhat smaller own-price elasticities; -0.09 for farm capital services and -0.04 for farm labor.

Farmers' adoption of GM corn and soybean varieties affects other production decisions. An increase in the adoption rate for GM soybean and corn varieties reduces the demand for all variable inputs. However, a weak tendency for GM soybean adoption to increase the supply of soybeans and wheat occurs but it reduces the supply of corn and livestock. A higher GM-corn adoption rate tends to reduce all outputs, but its largest impact is on the supply of wheat and livestock.

Farmers' adoption of GM soybean and corn varieties has been profitable. An increase in the adoption rate for GM-soybean varieties by one percentage point has a shadow-value payoff of about $2.7 million per year in the average Midwestern state (in 1996 prices). This compares with an estimated technology fee for switching one percentage point of the soybean acres over 1996 to 2004 from non-GM to GM soybeans of $757,000. Ignoring any short term discounting, this translates into a benefit-cost ratio of about 3.6. An increase in the adoption rate for GM-corn varieties by one percentage point has a shadow-value payoff of $26.8 million (1996 prices) per year in an average Midwestern state (in 1996 prices). This compares with an estimated technology fee cost for switching one percentage point of corn acres over 1996 to 2004 from non-GM to GM corn varieties of $515,000. This translates into a benefit-cost ratio of about 52. These benefit-cost comparisons are quite large and support continued higher use of GM corn and soybean varieties in the US Midwest.

Farmers in the US have experienced a high payoff to adopting GM corn and soybean varieties, and the new crops have been environmentally friendly but a small amount of resistance by target pests has surfaced. This is expected because of the evolving nature of target pest.

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The case of Bt maize in the EU

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1. Introduction

Insect resistant (Bt) maize in the European Union (EU) reached 91,193 ha in 2010 (James, 2011) which represented 2.28% of the total grain maize area in the EU-15 and 1.71% of the total grain maize area in the EU-25. Only six countries of the EU planted Bt maize for commercial use. These countries in descending order of hectarage were Spain, the Czech Republic, Portugal, Romania, Poland and Slovakia. Spain had the largest hectarage of Bt maize in the EU with 74.26% of the total Bt maize area in the EU in 2010. The adoption rate of Bt maize in Spain has been stable around 21% since 2007 (MARM, 2010). Most Bt maize is used in animal feed and currently all compound feed sold in Spain is labelled as genetically modified (GM) with the exception of organic feed (Brookes et al., 2005). However, as in other EU countries a specific new market for non-GM compound feed may emerge also in Spain (Brookes et al., 2005).

2. Materials and Methods

In order to evaluate the economic performance of Bt maize relatively to conventional maize in Spain a survey amongst maize farmers was conducted between June and July 2010. A total of 180 farmers were interviewed by phone including 119 farmers growing conventional maize and 61 farmers growing Bt maize. The questionnaire included questions on farm characteristics in 2009 such as crop hectarage, yields, prices or production costs as well as farmer's socio-demographic questions.

This paper has a double objective. First, the profitability of Bt maize when compared to its conventional counterpart is analysed after 12 years of experience growing Bt maize in Spain. Secondly, this paper establishes the limits of the higher profitability of Bt maize relatively to conventional maize. These limits are based on different scenarios that have an effect on inputs' costs and prices of harvested maize.

Economic performance of Bt maize when compared with its conventional counterpart can be evaluated through the difference in gross margin between both crops.

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3. Results

Results show incomes are 11.55% higher for Bt maize farmers than for conventional maize farmers, showing that Bt maize continues to perform economically better than conventional maize in Spain after 12 years of cultivation. Previous studies showed similar results at earlier stages of Bt maize adoption in Spain (Gómez-Barbero et al., 2008).

A profitability analysis of Bt maize was conducted by examining the thresholds at which the crop start to be profitable. Given the baseline scenario in 2009, different variables were modified to analyse the profitability of Bt maize when compared with its conventional counterpart under different situations. Scenarios where Bt maize price decrease and conventional maize price increase were considered. Results from the profitability analysis show that slight changes in Bt and conventional maize prices imply a great fall in the probability of Bt gross margin being greater than conventional gross margin.

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Challenges in Measuring the economic impacts of biotech crops in developing agriculture

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Introduction

Debates about transgenic crop varieties have often polarized public discussions about the potential of biotechnology to meet the needs of smallholder farmers, particularly in developing country agriculture. Governments need objective assessments, but such information is not easy to generate.

The ideology of the debate over biotech crops seasons not only the interpretation of the findings but also, in some cases, the methods selected for analysis. The methods used to assess impacts also suffer, as do any scientific methods, from limitations.

Growing transgenic varieties, like other new crop varieties, has social and economic consequences for small-scale farmers and their communities. Unlike other new crop varieties, however, transgenic crop varieties have raised ethical concerns that have not been raised before.

Thus, particular challenges are faced by researchers seeking to assess the impacts of biotech crops on farm households in developing agriculture. This presentation reviews the methods used by applied economics to measure impacts on farms, focusing on the first decade since their introduction (1997-2007). Advances from more recent work are also highlighted, and reference is made to a recently published meta-analysis by Finger et al. (2011).

Scope

We began with a systematic review of all literature published in English, French and Spanish, combining databases available on line, web-bibliographies related to biotechnology, references cited in published articles and direct communication with economists working on the research questions. Only peer-reviewed articles with a stated economics method, conducted in developing agriculture, were selected. After examining their content, a total of 321 articles met our criteria as of August 30, 2011. They are grouped by major economics research question, which corresponds roughly to the sectors of the economy (farmer, consumer, industry, trade), in Table 1.

Of the papers using primary data analysis, about half examine impacts on farmers (127). Studies of consumer acceptance and industry impacts are next in numbers (47,48). Analyses of international trade follow (33). The ratio of review articles to primary analyses appears to be high. There are several articles on the costs of regulation, biodiversity, and biosafety. The total numbers seem to have declined in recent years.

Table 1. Number of articles examining the economic impact of biotech crops in developing agriculture (through mid-2011)

	Pre- 2005	2006	2007	2008	2009	2010	2011	Total
Farmers	51	18	10	21	17	5	5	127
Consumers	14	13	4	9	4	2	1	47
Industry	17	6	6	13	5	1	0	48
Trade	17	6	4	2	2	2	1	34
Review findings	17	5	0	3	5	3	0	33
Review methods	7	3	2	2	2	1	0	17
Cost of Regulation	1	2	1	0	1	2	1	8
Others	0	1	0	0	1	2	3	7
Total	124	54	27	50	37	18	11	321

Note: Other includes biodiversity, biosafety

Methods Applied to Measure Impacts on Farmers

Smale et al. (2010) analysed the methods used to measure impacts on farmers through 2007, spanning the first decade since the introduction of biotech crops in developing agriculture. The most common approaches employed were partial budgets, followed by farm production and input use models. A small subset of articles used variety choice models based on revealed or stated preferences, value chain analysis, or mathematical programming. Only the partial budgets and econometric models are discussed here.

Most articles were based on analysis of Bt cotton, followed by Bt maize, and a few articles on HT soybeans and a small collection of articles on other crops (papaya, banana, rice, sweet potato, potato, eggplant).

Partial budgeting

Partial budgeting is the simplest approach used by agricultural economists to test hypotheses concerning the effects of Bt crops on yield losses from pests, insecticide use costs, labour use costs, and profits. The major limitations associated with this approach reside with the data used to construct them. Data sources are generally farm surveys, trial data, or company data. Some authors use several sources at a time. Trial data does not represent farm conditions well. Company data sources may be construed as potentially biased.

Constructing a sampling frame for farm surveys of biotech crops can be particularly costly and difficult due to lack of information and political sensitivities. Many of the first generation of studies are based on very small samples, reflecting the fact that they were implemented in the early phases of adoption. They also exhibit a placement bias, since initially, promotional programs were often initiated with a unique group of farmers—either because more efficient, or they were targeted for other reasons. This type of bias is often recognized by the authors themselves.

Conceptual limitations include the fact that most margins presented in early studies are gross, rather than net, and do not consider land or labor costs. A whole-farm perspective would provide a better indication of the impacts on overall resource allocation. In additional, the partial budget approach must be modified to better represent the conditions of farmers who are not entirely commercially oriented, whose families constitute the primary source of labor, and who purchase and sell on poorly functioning markets. The introduction of risk, through application of stochastic budgeting, has constituted an advance. Recall has often been used to measure insecticide use, although farmers are often unfamiliar with the names of the insecticides they apply, or mix them, or do not remember amounts applied. Some researchers have designed more effective protocols for monitoring pesticide use.

Econometric models of production and input use

Most econometric analysis of the impacts of Bt crops have served to test the same hypotheses with more advanced statistics. Other methods test the impact of adoption on production efficiency. The quality of econometric analysis, in turn, is based in part on the quality of the data. In some cases, the same small samples have been used for successive econometric analyses, entailing some test bias. That is, the number of independent authors and data sets is narrower than the number of articles published.

Early studies typically estimated yield response or production functions, or insecticide use equations, with a dummy variable included as an explanatory variable to test the effect of adoption. A major advance was the application of damage abatement models, recognizing that Bt, like insecticides, serve to reduce yield loss in the presence of pest pressures, rather than raise yields as does fertilizer.

Other challenges remain. By far the most important consideration is the bias associated with self-selection of more efficient farmers, or those with greater endowments and access to information and resources, into adoption. In the period through 2007, treatment of selection bias was uncommon in published studies. Since then, a number of studies have sought to control for selection bias using various methods, including Heckman models, instrumental variables, panel fixed effects models and propensity score matching. Randomized controlled trials have not yet been published, to our knowledge.

A related challenge has been posed by the fact that the Bt gene has variable expression depending on the gene construct and the host cultivar. Comparing Bt crops strictly to their isogenic lines, or controlling for host cultivar econometrically is not always feasible with farmer survey data.

A third major challenge is the endogeneity of decision to grow a Bt crop. Unobserved factors can affect both this choice, or the decision to use insecticides, and farm yields or other indicators of outcome. Presence of endogeneity was rarely tested in early studies, leading to potential bias in estimated impacts. Several articles are exemplary in their treatment of both selection bias and endogeneity.

Conclusions

Early published studies of the economic impact of biotech crops on farmers in developing agriculture exhibited several common methodological limitations. These were often exacerbated by political sensitivities. Many of these limitations have been addressed as research has progressed. However, the number of studies published per year appears to have declined in recent years. The number of traits studied, and of independent, ex post, farm studies, remains few. Continued scientific progress is necessary to overcome methodological limitations and conclusions must be drawn with caution.

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Welfare creation and distribution

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The purpose of this paper is to describe the major ways in which genetically modified (GM) plants have improved the welfare of society and which groups in which countries have benefitted and lost from this technology. Since other speakers are focusing on benefits to farmers and consumers, this talk will focus on the global distribution of benefits to agribusiness. It then discusses how the diffusion of GM benefits is shifting agricultural research and the implications of that shift for future benefits.

The first generation of GM plants were herbicide tolerant (HT) or insect resistant (IR) soybeans, corn, cotton, and canola. There is now a large body of farm level studies – much of it reported in this conference by Qaim, Huffman, Rodríguez, Smale, and Zilberman and others showing that these crops have done the following:

1. HT crops in countries and regions where weeds were already fairly well controlled have reduced the time that farmers use to control weeds and have allowed farmers to shift to safer herbicides. Farm level studies in most countries show little evidence that HT crops increase yield per unit of land, but there is evidence from Argentina that using HT soybeans has allowed an extra crop to be planted per year which increased the area of soybean cultivation by 100s of thousands of acres.

2. HT crops in developing countries where weeds are not well controlled through mechanical cultivation, herbicides, or hand weeding could see substantial yield gains from HT technology but this has only been documented in South Africa so far (Gouse et al. 2010) and Romania (Brookes & Barfoot 2009). In countries with few available jobs and low wages HT technology could reduce employment of poor labourers or family labour for weeding and increase use of herbicides.

3. IR crops in countries where the insect pests are well controlled have primarily allowed farmers to reduce their use of chemical pesticides, but they have also led to limited increases in yield per ha in some crops.

4. Adoption of IR crops in countries and regions where insect pests were not well controlled primarily increases farmers' yields but in some cases reduces pesticide use as well.

This same literature shows that the welfare of farmers who adopted these technologies increased because the reduction in cost of production led to increased profits, saved on their time so that they could earn more money in other jobs, and in some cases improved their health through reducing exposure to dangerous pesticides. The total of the increased profits can be summarized as producer surplus due to GM plants which has been documented extensively. A few studies have quantified the value of time saved (Fernandez-Cornejo et al. 2005) and health of farmers due to reduced pesticide use (Hossein et al 2004).

Globally most of the benefits have gone to commercial farmers but because the technology is scale neutral, small farmers have been able to benefit as much or more per ha than large farmers and millions of small farmers have benefitted from the technology. IR cotton production has benefitted 6.5 million small cotton farmers in China, 6.3 million small farmers in India, 600,000 in Pakistan, 400,000 in Myanmar, and 100,000 in Burkina Faso. IR yellow maize benefits 250,000 small farmers in the Philippines and IR and HT white maize benefit 1,000s of small farmers in South Africa (ISAAA 2011).

Consumers' welfare increased because farmers responded to these profit opportunities by producing more grain, oilseeds, and cotton which lowered prices. Consumers' welfare increased because they could buy more at lower prices. Some of these "consumers" of agricultural crops are agricultural processing industries. For them the lower priced agricultural products reduce their costs of production, increasing their profits. Part of this will go into increased profits of the processing industries, part will be passed on to the final consumers through lower prices of cooking oil, meat, processed food and cotton cloth.

The other increase in societies' welfare is the increase in profits of the biotech companies through technology fees from the sale of genetically modified plants (Moschini and Lapan 2007). The seed companies that licensed biotech also got higher profits which could also be considered innovators' rents (Pray and Nagarajan 2010).

Distribution of benefits and losses to different sectors of the economy

Due to strong IPRs and other government policies, biotech firms capture a substantial part of the economic surplus from GM plants in wealthy countries. Qaim (2009) summarizes the findings of studies in the US.

- IR cotton - Farmers 37%, Consumers 18%, Biotech industry 45%
- IR maize - Farmers 50%, Consumer 19%, Biotech industry 31%
- HT soybeans - Farmers 20% Consumers 20%, Biotech industry 60%

In developing countries because of government policies such as weak intellectual property rights farmers captured most of the benefits rather than the industry. A recent article on the division of benefits between the biotech industry and farmers for all major crops based on available micro-level studies (Brookes and Barfoot 2009) showed that in developing countries in 2007 industry captured 14% of the benefits through technology fees while in developed countries industry captured 33%.

In the initial stages of the use of GM plants the benefits to farmers were concentrated in the US and Canada but now these benefits have spread to developing countries in Latin America, Asia and a few countries in Africa. The division of benefits between developed and developing countries has shifted. The value of farmers' increased income from GM crops in 2007 in developing countries was $5.8 billion while the value of farmers' income from GM crops in developed countries was $4.6 billion (Brookes & Barfoot 2010). Farmers' benefits from insect resistant maize were still primarily in the US, but most of the benefits from HT soybeans are obtained by farmers in Argentina and Brazil and the benefits from IR cotton went mainly to farmers in China and India.

Consumer benefits are more widely spread than farmer benefits because many countries that do not allow production of GM plants do allow consumption of them. Europe, China, and India do not allow production of GM soybeans. In 2009 Europe imported primarily for animal feed 23 million tons of soymeal and 12.6 million tons of soybeans from South America and the US which is mostly produced by GM soybeans. China imports 45 million tons of GM soybean for cooking oil and animal feed and 2.4 million tons of oil but does not grow soybeans (FAOSTAT), and India imports 1.1 million tons of soybean oil. In Africa Kenya and other countries import white GM maize for direct human consumption from South Africa but does not allow production of GM maize. In addition consumers of maize, soybean, canola, and cotton in all countries benefitted through lower prices of these crops as is shown in Sexton and Zilberman (2011).

As with any new technology certain companies will have their profits reduced due to the introduction of new technology. Many pesticide producers and distributors will lose profits as their sales of insecticides are replaced by IR crops and older herbicides will be replaced by glyphosate and glufosinate. Seed companies that do not or cannot license GM traits may lose market share to GM varieties.

Farmers who cannot adopt GM technology but face lower prices for their cotton, maize or oilseeds because of the productivity increases in other parts of their country or in other countries can also lose profits. For example, the Western China cotton region does not have a bollworm problem and so it does not get the cost reductions from IR cotton, but it does receive lower prices because of increased production in Central and Northern China. Others who could lose are non-GM producers or organic producers who lose markets because of mixing or cross-pollination.

Impacts on Science

Will the shift of the benefits of GM technology to farmers in developing countries lead to more research on crops other than maize, cotton, soybeans, and rapeseed? Will GM technology be targeted to problems of the tropical agriculture?

Brookes and Barfoot (2009) estimate that the biotech industry earned about $1 billion in royalties in developing countries and $ 2.2 billion in developed countries in 2007. The numbers in both regions have increased since then but grew faster in developing countries in recent years. Fuglie (2009) found that global private research by the seed industry, driven in part by the actual and potential profits from sales of GM traits, almost doubled in real dollars from 1995 to 2007, while research on pesticides declined by about 20%.

The rapid growth of sales of GM products and the technology fees in developing countries has also pulled biotech research into the countries where farmers are using GM seeds. The technology fees give biotech companies money to invest in local research and the rapid growth in the market for GM holds promise of greater profits in the future. In the last ten years Monsanto has invested in major biotech research facilities in Brazil, India, and China. DuPont has invested in basic biotechnology labs in China and India. In addition there have been major investments in the biotechnology research by multinationals based in the developing world such as Advanta (India) and Pannar (South Africa), by national firms particularly in India, and governments of China, Brazil and India.

These programs are developing technology for the needs of the developing world – GM white maize in South Africa and hundreds of hybrids of Bt cotton to suit local agricultural conditions in India have already been developed by the private sector. DuPont, Bayer Agrosciences and other major biotech companies have major rice research programs for Asia which were virtually non-existent 20 years ago. These investments suggest that more GM technology for small farmers in Asia will be available in the near future.

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Impacts of biotechnology on global productivity and world food prices

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The early literature on the adoption of biotechnology mainly in the United States found that the high yield effects of genetically modified (GM) varieties were modest. Most of their benefits were in terms of reduced pesticide costs, reduced exposure to risk, and reduced effort. However, studies that assessed the impacts of biofuel in developing countries, in particular, for Bt cotton, show very high yield effects. This difference in impact can be explained by the damage-control framework of Lichtenberg and Zilberman. The early GM traits were aimed at reducing pest damage. They include the insertion of bacillus thuringiensis (Bt) to control insects and to build up resistance to herbicides to reduce weed damage. When GM varieties addressed pest problems that were treated before by pesticides, the yield effect was low. But, when they treated pests that had not been controlled before, the yield effects were significant. Indeed, a significant body of literature confirmed these findings of reduced pesticide use in some countries and increased yield in other countries. In addition to the yield effect associated with reduced damage, the adoption of GM increased yield because it made the application of complementary inputs, such as fertilizer, more profitable.

Much of the literature contains studies that assess the impacts of GM at specific locations. However, Sexton and Zilberman present results that use 20 years of data for more than 100 nations of major field crops and assess the yield effect of GM varieties on a per-acre basis for each of the crops. They find that crops that adopt GM, such as cotton and corn, have much higher increases in yield than wheat and rice for example. Furthermore, among the crops that have adopted GM, the higher yield effects occur in developing countries. For example, they estimate that, in developing countries, the yield effect of cotton, both through damage reduction and complementary inputs, is greater than 100 percent while, in developed countries, it is only 22 percent. In maize, the yield effect per acre in developing countries is 50 percent and in developed countries, 15 percent. In the case of rapeseed, the yield effect in developed countries is about 25 percent. These impacts vary across countries and, in some cases, the adoption of GM varieties actually reduced average yield because it enabled the expansion of agricultural land.

Soybeans present an interesting case. While the yield effect in developing countries may reach 30 percent, the main benefit of GM varieties is increased acreage. Soybean acreage has tripled over the last 30 years, and GM is responsible for much of it. In particular, Roundup Ready soybeans controlled weeds that allowed the double cropping of soybeans with wheat in Argentina and Brazil. The increased soybean output in Argentina allowed the growing demand for soybeans in China to be met. Analysis translating some of the yield effects to agricultural supply suggests that the introduction of GM varieties reduced the price of corn by 13 percent to 30 percent and the price of soybeans by 20 percent to 40 percent, depending on the elasticity. It also affected the price of wheat because it enabled the growing of other crops on less land. The increase in the productivity of cotton also contributed to the increased supply of other crops by developing land from cotton and other field crops, such as corn. Actually, the price-deflating effect of GM varieties was of the same order of magnitude but in the opposite direction of the price-inflating effect of biofuels.

If GM traits were adopted in Africa and Europe, then the increase in output of corn would have been of the same order of magnitude as the amount of corn diverted to biofuels. The increase in output in vegetable oil would have been much larger than the amount of vegetable oil used for biodiesel. If GM traits would have been introduced to wheat and rice, globally, they could have reduced substantially much of the food-price inflation problems that we face today.

Finally, the adoption of GM tends to reduce greenhouse-gas emissions because of the increased productivity that reduced acreage as well as the adoption of low-tillage that reduced emissions. There are field experiments that suggest that the productivity effect of GM on special crops is of the same order of magnitude as in field crops. The ban on GM in Europe slowed the development of new trade that could have both improved the agricultural yield further and increased productivity by improving the quality and the digestibility of food and feed.

Case studies of supply chain analysis and segregation in the EU

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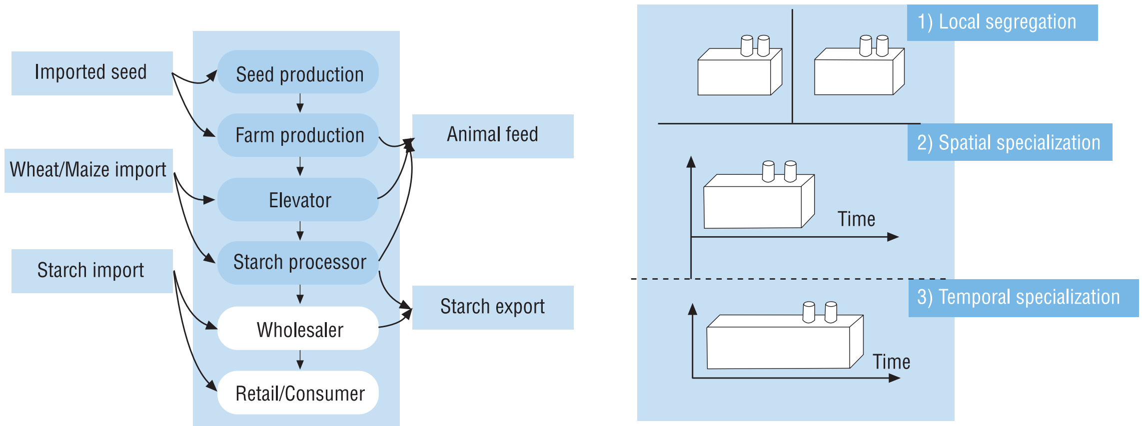
The worldwide relevance of genetically modified (GM) plants is growing year by year in agricultural production. In 2010 around 150 million hectares were grown with GM commodities in 2009 countries (ISAAA, 2011) with GM soybean, maize, cotton and rapeseed amounting for more than 85 % of the global GM production area. Despite this situation, the EU and in particular the food industry in Germany has developed an almost strict no-GM policy with respect to GM ingredients in foods which have to be labelled according to the existing EU regulations. Furthermore, actors operating in a specific value chain are required to install an appropriate documentation and traceability system. If food companies intend to introduce food products on the EU markets which contain GM ingredients, they have to cope within these regulations.

In this contribution the results of cost analysis done within the Co-extra project are considered in order to estimate possible economic impacts of co-existence along food supply chains in EU countries. For this purpose a specific modelling approach was used which allows single crop chain consideration as well as supply chain comparison of different food products and/or different countries. Taking the results of the analysis, it is possible to extrapolate the analysed cost into complete fields of industry (e. g. wheat starch industry for food production) or consider processed foods with several affected food ingredients (e. g. frozen food industry).

The cost calculations for co-existence in food supply chains measures at each level of the value chain follow the principle to aggregate all incurred costs for cultivating and transportation of crops or processing of the raw material crops on the different levels and to increase the price of the final product at each level. This means that e. g. the commodity price of wheat flour is increased by the costs of co-existence measures on the farm level in order to comply with the threshold of 0.9 % for adventitious presence of GM material. The resulting price for secured non-GM wheat is automatically the non-GM commodity price in the next level of the value chain. This scenario is currently a purely hypothetical one as EU consumers don't accept GM products and the European markets are not disposed for GM food. The aim of this study was to detect critical points of the food processing companies and define additional costs that appear when certain GM food commodities are unavoidable and the pressure of competition is so high that the food processor has to turn to parallel production of labelled GM and non-GM products.

Especially on processing levels of the value chains (elevator, crusher, processor), the composition of occurring cost types is strongly oriented on the considered processing strategy (see figure 1). Depending on several preconditions (e. g. capacities, size, and location) and parameters (e. g. regulatory framework, co-existence situation, and company's overall concept) each involved actor has to choose its own strategy, whereby economic considerations are surely the crucial factor.

Figure 1. Display of the analysed wheat starch supply chain (left) and possible options to manage co-existence at processing level (right)

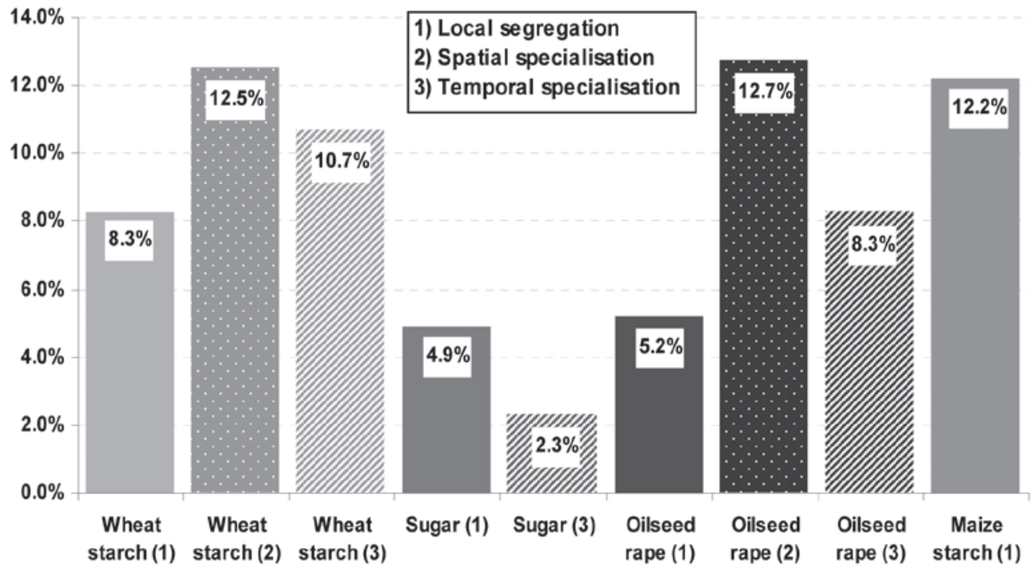


Each of the three possible strategies (figure 1) implies different benefits, critical and weak points and extra costs like higher admixture risks and higher efforts in personnel training and monitoring in spatially or temporally separated production lines at one company. The total segregation in separated production on two sites may cause higher transport distances but lower risk of commingling GM and non-GM commodities and processed food products.

On the basis of the case studies conducted, we can conclude that every actor and supply chain level will be economically affected by an emerging co-existence situation. As the additional commodity costs is the most relevant cost category at the elevator and processor level, the farm level borne co-existence costs are of particular importance. In this respect, the most determining factors are the isolation measures to ensure the 0.9 % threshold of GM admixture, the threshold determined for "GM-free" seeds, the farm structure and the regional penetration level of GM commodities etc., which all finally influence the price premium between GM and non-GM commodities at farm level.

According to the results of the analysed food supply chains, significant additional costs are expected by organizing co-existence between GM and non-GM products in the value chain from production of farm crops up to the processing level of the single supply chains and by maintaining mandatory (or voluntary) thresholds and regulations. Depending on factors like crop requirements, farming, storage and elevating systems, processing strategies, monitoring managements, etc., the total additional costs of co-existence and product segregation systems can rise up to 12.5 % of production turnover for non-GM rapeseed oil in Germany (figure 2). In case of non-GM sugar the price loading amounts to 2 % to 5 % and in case of non-GM wheat starch to 8 % to 13 %. Respecting supply chains in different countries, different cost structures can be noticed because of special legal frameworks and company infrastructure. Therefore, variable higher prices for non-GM rapeseed oil are determined in Denmark (8.3 % of turnover), Switzerland (5.3 %) or Poland (3.6 %).

Figure 2. *Comparison of German food crop supply chains (processor level); figures in % of production turnover*



Source: own calculations

Interpreting the results of this study, the present food industry's uncertainty with and lack of knowledge in operating GM products has to be considered as in most food industry sectors the question of co-existence is strongly disclaimed at the moment. Of course, an implementation and permanent running of co-existence and segregation systems in the food supply chains can decrease the additional costs due to savings e.g. in the testing requirements of ingredients or routine procedures during the documentation process. Otherwise, systems for segregation and maintaining the GMO threshold of 0.9 % hardly bear any significant additional benefits for producer, retailer or consumer as this would be the case in organic, health-related (e. g. anti-allergen) or fair traded production lines. It should not be expected that European consumers are not willing to pay extra money for product differentiation in the sense of a labeled food product that contains GM materials below the threshold of 0.9 % (Jones et al., 2009). Thus, food processing companies might not be willing to pay the incurred costs of co-existence measures occurring along the line of the supply chains of certain product ingredients. The case studies also expose that the qualification of food processors in terms of infrastructure and resources endowment to operate both, GM and non-GM commodities in parallel is hardly assured. Especially for companies with restricted facilities (SMEs) the conversion to parallel production will be difficult to manage. Only few European companies which command already sufficient existing facilities to manage parallel GM and non-GM food production might have the opportunity for specialization and supply the market with GM and non-GM food products if the demand situation changes. Conversely, it can be expected for the coming years that additional branches of the food industry in the EU will be faced with the challenge of an increasing risk of GMO-admixture mainly due to the globally growing cultivation area of GM crops. This will lead to additional and increasing costs to further realise the "prevention-strategy" which is currently adopted by most companies of the food industry in the EU even if very few (or no) GM plants are cultivated in the EU.

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Menrad et al., 2009. Co-extra GM and Non-GM supply chains: their co-existence and traceability: cost and benefit analysis of selected value chains for end use products D 3.9

Coexistence of GM and non-GM supply chains in the EU: policy framework and economic aspects

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Coexistence of conventional, organic and GM crops can be regarded as (1) an economic issue of (2) preserving the choices for consumers and farmers among different methods of production by (3) controlling agro-ecological dynamics through measures of segregation (4) embedded in a broader regulatory framework of (4a) labeling and (4b) approval for GM crops. The economic problem of coexistence, therefore, always consists of at least three framing factors: first, consumer and farmer preferences for different production methods; second, the agro-ecological dynamics depending on the biology of the crops concerned and the agro-ecological environment in which they are released; and, third, the broader institutional framework. It should be noted that all these key factors vary internationally, nationally and even regionally. Different preferences on the demand and supply sides are fundamental and are suspected to affect the institutional environment for GM labeling and approval (e.g. Gruère et al., 2008; Crespi and Marette, 2003; Kalaitzandonakes and Bijman, 2003; Bernauer and Meins, 2003)[1]. Agro-ecological dynamics are crop- and location-specific and are extensively addressed in the agronomic literature (e.g. Heuberger et al., 2010; Jarosz et al., 2005; Ma et al., 2004).

Agro-biological dynamics – in particular, cross-pollination and other forms of admixture – do not by themselves generate any economic problems. The latter emerge purely from the social construction of what is considered as GM, conventional or organic and whether they need to be approved or labeled in order to be marketed legally (Bender and Westgren, 2001; Beckmann and Wesseler, 2007). In other words, the issue is related to the legal definition of goods and the segmentation of markets by labels and approval procedures.

Over the past two decades, two distinct approval and labeling regimes have emerged which largely distinguish the US and Canada from Europe. At the European level responsibility for risk assessment and risk management is divided. Risk assessment based on scientific evidence is prepared by the European Food Safety Authority (EFSA), whereas the approval decision is complex and political, involving the Commission of the European Commission (EC), the European Council and the European Parliament (Wesseler and Kalaitzandonakes, 2011). Differences also exist regarding labeling regimes (Gruère et al.,

1 To be sure, there are many actors who may influence labelling and approval procedures and consumer and farmer preferences, e.g. food manufacturers, retailers, NGOs or the biotechnology industry. For the political economy of GM policies, see e.g. Graff et al. (2009).

2008): whereas the U.S. and Canada do not require any GM labeling and allow for voluntary labeling of non-GM food and feed, the EU introduced strict, mandatory labeling and traceability of GM food and feed (Regulation [EC] No 1830/2003). Whereas under the mandatory labeling and traceability system the GM sector has to bear the costs of labeling, documentation and tracing, it is otherwise for the non-GM sector (Phillips and Isaac, 1998).

In Europe, a system of labeling has been developed for defining goods on the basis of product standards. If a food or feed product contains or consists of a GM organism (GMO) or is produced from or contains ingredients produced from GMOs it needs to be labeled. If a product contains less than 0.9% of a single GM event due to adventitious or technically unavoidable presence, it does not have to be labeled as GM[2]. This standard applies currently for conventional as well as for organic food and feed, although the organic food sector requires even higher standards.

The institutional differences between North America and Europe are important for understanding and analyzing the regulation of coexistence. Policies governing coexistence can be differentiated into ex-ante regulations and ex-post liability rules. This differentiation is useful, as the economic implications of the two also differ (e.g. Kolstad et al., 1990; Posner, 2007; Shavell, 1987).

EU Member States are progressively regulating coexistence at the national level (CEC, 2009). While contemporary law and the incentives for GM-farmers to invest in fencing would already solve many coexistence problems, the European Commission (CEC) (2003, 2009) has published guidelines for coexistence regulations to enable farmers "… to make a practical choice between conventional, organic and GM crop production, in compliance with the legal obligations for labelling and/or purity standards." The guidelines include a number of measures member states may choose to achieve coexistence. In general, measures include ex-ante regulations and ex-post liability rules and member states have adopted them at different levels. Beckmann et al. (2012) provide a list of those regulations and rules and discuss them in detail.

The coexistence measures should enable non-GM farmers to deliver their harvest with a possible presence of GM material lower than the pre-mentioned labelling threshold (Messean et al, 2006). Ex-ante regulations constitute practices that a farmer has to follow if s/he desires to plant GM crops. These regulations increase the current regulatory costs, while reducing ex-post liability costs. Following Beckmann et al. (2006), ex-ante regulations in the EU can be distinguished with regard to prohibition of cultivating GM crops in specific areas, approval procedures, registration, and information duties requested from GM farmers, as well as technical segregation measures. This also includes the transaction costs of informing the neighbours and/or reaching an agreement with them[3]. Ex-post liability costs include possible damages, due to admixture with GM crops, that GM farmers have to compensate; these depend on existing national laws, which are quite diverse within the EU (Koch, 2008). The ex-post liability rules also result indirectly in ex-ante precautionary measures, due to the inducing of adaptive behavior by GM farmers, such as the planting of windbreaks and negotiations with neighbors about possible damage settlements (Beckmann, et al., 2010).

2 The details of the EU regulations on labelling are provided by CEC (2003).

3 In this case the good being exchanged is the right to plant Bt maize and the transaction costs fall under category 1: the costs of discovering the right price, and category 2: the costs of negotiating the terms of an exchange, of the transaction costs mentioned by Coase as discussed in Fox (2007).

Most of the studies investigating the coexistence effect at farm level analyse ex-ante distance requirements as reviewed by Demont et al. (2009) in the form of isolation distances and pollen barriers. An important factor of distance requirements is the impact on adoption of the technology. First of all, distance requirements tend to reduce the adoption rate. A simulation model by Demont et al. (2008) demonstrates the effect. Even one non-GM farmer within a given landscape can substantially limit adoption of GM crops by other farmers as the study by Groeneveld et al. (2012) shows. Secondly, mandatory distance requirements increase the minimum farm size for adoption and hence discriminate against smaller farms (Soregaroli and Wesseler, 2005), while via collaboration (Beckmann et al., 2010) and technical measures (Ceddia et al., 2009) this effect can be reduced. Consmüller et al. (2009) in a study analysing the adoption of Bt maize in Germany find the maize area grown per farm is the single most important factor explaining regional and temporal variance in Bt-maize adoption. While distance requirements add extra costs and discriminate against smaller farms, Beckmann and Wesseler (2007) and Beckmann and Schleyer (2007) argue the regulatory environment will provide incentives for farmers to cooperate to reduce coexistence compliance costs. Similarly, Furtan et al. (2007) argue the regulation of GM crops in Canada provides incentives for organic farmers to collaborate. If the legal environment allows farmers to cooperate and reduce coexistence compliance costs the effect of coexistence regulations on adoption and in particular minimum distance requirements and their effect on farm size might be less pronounced. A case study of Bt maize farmers from Portugal confirms the possibility to reduce coexistence compliance costs to almost zero via cooperation among farmers (Skevas and Wesseler, 2010).

While in general GM and non-GM farmers have been able to coexist without any major problem in those countries where GM crops have been approved for commercial cultivation (Czech Republic, Poland, Portugal, Romania, Slovakia, Spain), experiences at the EU level show coexistence problems emerge in seed and honey production. The problems in seed production in many cases can be addressed via proper handling and testing, the European Court of Justice's decision on honey has the potential to block GM crop cultivation within the EU.

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EU coexistence policies may shape future adoption of GM technology by EU farmers

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Introduction

Regarding the cultivation of genetically modified (GM) crops, the European Commission recognises that 'European farmers should have a sustainable possibility to choose between conventional, organic and GMO production', underlining that economic damages or losses derived from the introduction of genetically modified organisms have to be avoided (European Council, 2006). Specific segregation measures during cultivation, harvest, transportation, storage and processing are required to ensure coexistence. These segregation measures should be targeted to ensure that non-GM harvests do not contain adventitious GM presence beyond the permitted 0.9% established by the EU. Currently, most of the European Member States have adopted or are in the process of developing legislation on measures that ensure coexistence between GM and non-GM crops. By February 2009, 15 EU countries had adopted specific legislation on coexistence (Austria, Belgium, the Czech Republic, Denmark, France, Germany, Hungary, Latvia, Lithuania, Luxemburg, the Netherlands, Portugal, Romania, Slovakia and Sweden) (European Commission, 2009). Since only Bt maize is approved for cultivation, most of the Member States' current legislation includes specific measures which relate only to GM maize cultivation.

The main objective of this article is to provide an insight into the factors affecting the *ex ante* likelihood of adoption of some GM crops, including economic, environmental, technical factors and the regulations to ensure coexistence highlighted above. The analysis focuses on two particular GM crops, GMHT OSR and GMHT maize, both not yet approved for cultivation within the EU but widely adopted by farmers elsewhere. Previous research identified that the producer's adoption depends on the current and perceived future profitability, the convenience of the new technology (i.e. ease of use relative to the current technology used), environmental concerns and uncertainty of outcomes (Hillyer, 1999; Breustedt *et al.*, 2008). Coexistence policy is specific to the EU and may shape GMHT adoption in the EU. Few studies have focused on the effect of spatial coexistence measures on GM adoption using simulation techniques (Demont *et al.*, 2008 and 2009). However there is a lack of studies on the effect of a wider number of policy regulations (registration, segregation measures and insurance covering) on adoption currently under debate in the EU. This article aims to help overcome this shortage, through the evaluation of the effect of regulations associated with coexistence between current and new technologies, on the adoption of new technologies. The incorporation of such measures or regulations in the analysis is crucial for examining

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the potential level of adoption of GM technology if measures to ensure coexistence between the current and the new technology are to be implemented.

The surveys

In order to estimate farmer's willingness to adopt GMHT OSR and GMHT maize, a survey questionnaire was designed including questions on farm characteristics, and a wide list of reasons which may encourage/dissuade farmers from adopting GM crops including economic, environmental, technical, administrative aspects, and socio-demographic farmers' characteristics.

A total of 426 farmers were interviewed face-to-face in the Czech Republic, Germany and the United Kingdom on their willingness to adopt GMHT OSR during March and July 2007. During the same period 280 farmers were interviewed in France, Hungary and Spain on their willingness to adopt GMHT maize. Therefore, the total number of interviews is greater than the minimum sample size to ensure that all countries are adequately represented at EU level for each crop.

Conceptual framework

This paper studies the acceptability and potential adoption of two new crops, GMHT OSR and GMHT maize. The willingness to adopt these crops (WTAd) depends on the utility farmers derive from growing GM alternatives. In this paper, as it was mentioned above, WTAd and farmers' utility may be influenced by a number of factors related to economic benefits, efficiency and facilitation of weed control or conservation tillage. WTAd models were set up in an ordered probit regression framework in which the dependent variable is given as a likelihood of farmers adopting GMHT OSR or GMHT maize, on a 5-point scale.

In order to identify those factors that may influence GMHT crops' adoption, farmers were asked to evaluate a number of reasons according to how important they considered them. Within these factors we distinguished economic aims, reasons of disbelief, the implementation of coexistence measures and other socio-demographic issues.

Estimation results

Table 1 shows the results from the ordered probit model estimated for both GMHT OSR and GMHT maize. A likelihood ratio test was carried out to assess the goodness-of-fit of the models. These tests indicate that the models had satisfactory explanatory power.

Most of the estimated coefficients were statistically significant for GMHT OSR. The sign of a parameter estimate indicates how the associated explanatory variable is related to the willingness to adopt. Thus, the positive signs for the PROS variable in both models support the hypothesis that a farmer's willingness to adopt GMHT OSR and GMHT maize increases as farmers' own positive aspects such as economic, ease of use and environmental benefits become relevant in their decision-making.

Farmer's willingness to adopt GMHT OSR/GMHT maize decreases with the degree of importance assigned by farmers to negative views towards adoption (CONS), which include both own motivations and

Table 1. Determinants of farmers' willingness to adopt for GMHT OSR and GMHT maize

	GMHT OSR	GMHT maize
Explanatory variable	**Coefficient sign(1)(2)**	**Coefficient sign(1)**
Constant	+ ***	+ ***
PROS	+ ***	+ **
SNORM	-	-
CONS	- **	- ***
COEX	- **	- *
SEPARATION	-	- *
AGE	-	+
EDUCATION	+	-
SIZE	+	+
INCOME		+
GE	+ *	
CZ	- ***	
FR		-
SP		+

(1)+ means a positive sign of the coefficient whereas – shows a negative sign of the coefficient
(2) statistically significant at the 0.10 level of significance, **at 0.05-level, ***at 0.01-level*

farmer's perception of social pressures on him to not use the new technology. Also, coefficients associated with coexistence variables (COEX) show a negative sign in both models. This suggests that farmers for whom coexistence measures are crucial in their decision are less likely to adopt GMHT OSR/GMHT maize than those for whom such measures are irrelevant. The factor accounting for the individual perception of social pressures to adopt GMHT crops (SNORM) is found to be irrelevant in determining the probability of adopting GMHT crops.

Coexistence measures were found to hamper the probability to adopt GMHT crops. If separation distances of 25m between conventional and GM crops were put in place maize farmers' would be less likely to adopt GMHT maize.

Farm size was not found to be determinant in a farmer's willingness to adopt GMHT OSR/GMHT maize. This result may seem surprising since the impact of farm size on adoption is highest at early stages of the diffusion of an innovation, becoming less important as diffusion increases (Fernandez-Cornejo et al., 2001). However, this result is due to the significant correlation between farm size and other variables included in the analysis such as countries (p-value<0.01), which dilutes the effect of farm size in explaining adoption. Indeed, the correlation between GMHT OSR/maize adoption and farm size is positively significant (p-value<0.05). Among the socio-economic characteristics included, age, education and income none was found to be determinant in a farmer's willingness to adopt GMHT OSR/GMHT maize. This does not necessarily mean that socio-economic factors such as age, level of education or income have no role in explaining GMHT adoption. They may be influencing indirectly the probability of adopting GMHT through other determinants such as PROS and CONS, hence the effect dissipates.

Considering a farm's location, farmers in Germany were more likely to adopt GMHT OSR than farmers in the UK (benchmark country for OSR), being Czech farmers less likely to adopt that farmers in the UK. In the case of maize farmers, no difference between countries with regard to likelihood of adopting was found.

Conclusions

To conclude we emphasize that the EU coexistence policy is an interesting case worldwide to ensure the farmer's freedom of choice between cultivating GM and non GM crops. This is ensured through the implementation of coexistence measures to prevent admixture. By distinguishing between GM and non-GM products the EU policy generates a situation in which externalities associated with GM crop production (admixture) may occur. This market failure, derived from the way in which the EU interprets the introduction of a new technology, gives the public sector a reason to implement coexistence measures to prevent admixture (internalize the externality). According to this view the innovators (GMHT growers) are the externality producers and the ones who should bear the costs associated with coexistence measures. This effectively means that their average costs are increased rendering GM technology relatively less competitive than non-GM technologies and GM producers from outside the EU, and obstructing GM adoption.

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The Global Agricultural Supply Chain: Feasibility, Costs and Opportunities for Coexistence

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Since their initial commercialization in the mid-1990s, the introduction and adoption of biotech varieties has continued unabated in some key commodities including maize, soybeans, cotton, and rapeseed. In 2010, 29 countries grew biotech crops on 148 million hectares (James 2010). The broad adoption has been driven by farm-level yield and efficiency gains which have translated into billions of dollars of economic benefits every year (e.g. Brooks et al., 2010; Carpenter 2010; Qaim, 2009).

Maize, soybeans, cotton and rapeseed commodities are broadly traded in international markets and the bulk of imports and exports of such commodities are generally concentrated among a few key countries. For instance, the world share of the top five soybean importers exceeds 80% and the world share of the top five soy meal importers is almost 60% (Table 1). The EU the largest importer of soybean meal and the second largest importer of soybeans.

Table 1 Top 10 Importers of Soybean Commodities by Tonnage (Avg. 2007/08 – 2011/12)

Soybean Meal			Soybeans		
	1000t	**% of World**		**1000t**	**% of World**
EU-27	22,057	40%	China	49,636	59%
Indonesia	2,689	5%	EU-27	12,897	15%
Vietnam	2,464	5%	Mexico	3,492	4%
Thailand	2,310	4%	Japan	3,286	4%
Japan	2,025	4%	Thailand	1,812	2%
Republic of Korea	1,740	3%	Indonesia	1,571	2%
Philippines	1,729	3%	Egypt	1,514	2%
Iran	1,447	3%	Turkey	1,303	2%
Mexico	1,436	3%	Republic of Korea	1,180	1%
Canada	1,199	2%	Iran	987	1%

Source: Based on USDA PS&D database

Table 2. Top 10 Soybean and Meal Exporters, Avg. 2007/08 -2011/2012. (1000MT)

Soybean Meal			Soybeans		
	1000t	% of World		1000t	% of World
Argentina	26,647	47%	USA	37,079	42%
Brazil	13,314	23%	Brazil	30,076	34%
USA	8,445	15%	Argentina	10,563	12%
India	4,215	7%	Paraguay	4,851	6%
Paraguay	1,201	2%	Canada	2,309	3%
Bolivia	1,029	2%	Uruguay	1,387	2%
China	826	1%	Ukraine	616	1%
EU-27	475	1%	China	287	0%
Norway	159	0%	S. Africa	141	0%
Canada	143	0%	Bolivia	70	0%

Source: Based on USDA PS&D database

Table 3. Maize and Soybean Hectareage and Biotech Adoption among primary exporters in 2009

	Maize		Soybeans	
Country	Harvested Hectares	% biotech	Harvested Hectares	% biotech
USA	32,169,000	85%	30,907,000	92%
Brazil	12,925,000	36%	23,500,000	71%
Argentina	2,750,000	83%	18,600,000	99%
Canada	1,142,000	84%	1,380,000	72%
Paraguay	600,000	0%*	2,680,000	90%
Uruguay	96,000	82%	863,000	99%
Bolivia	310,000	0%	960,000	78%

** biotech maize has not been approved in Paraguay; however, USDA FAS estimated that 90% of the 2009 hectareage was planted with biotech hybrids brought in from neighbouring countries*

Sources: ISAAA, USDA

The bulk of these soybean products, but also other biotech commodities, come from a few major exporters. For instance, Argentina, the US and Brazil capture 88% of soybean and 85% of soy meal global exports (Table 2) and similar high concentrations are observed in the global exports of maize, rapeseed and cotton.

Major exporting countries have led the adoption of biotech crops. For instance, except Brazil, the levels of biotech maize and soybean adoption ranged 70-99% in all major exporting countries in 2009 (Table 3). Even in Brazil, biotech soybean and maize adoption has been rising rapidly and looks to reach levels similar to those of other major exporters in the next few years. Adoption of biotech varieties among top rapeseed and cotton exporters is similarly high. Given these adoption patterns, biotech crops represent a substantial share of the maize, soybeans, cotton and rapeseed commodities traded in international markets.

Non-GMOs, Unapproved Events and Segregation

The pervasive adoption and trade of biotech crops by key exporting countries need not be a problem in international trade except in cases where (a) there is demand for non-GMO commodities in some importing countries; and (b) when GMO varieties approved for cultivation in one or more of the major exporting countries remain unapproved in importing countries (a case of asynchronous approvals)[1]. In such cases, efforts are made to separate non-GMO or unapproved varieties from the commodity stream (where all varieties produced are commingled) through segregation and coexistence measures. Segregation and coexistence must succeed in keeping segregated varieties and commodities from seed to agricultural production and all the way through the supply chain while sharing the same land and infrastructure (storage, transport, ports, etc). These require reengineering of the standard commodity production and supply chain operations.

Because grains are bulky and relatively expensive to transport and store while their final unit value is relatively low, commodity supply chains control operational costs and facilitate trade through aggregation. Grain from numerous farms and storage facilities are constantly mixed throughout the supply chain resulting in perfectly fungible and divisible product streams. This fungibility facilitates the efficient use of discrete storage, transport and processing assets and yields significant economies of scale.

In segregated supply chains a primary objective is to ensure the absence of GMOs or unauthorized grains from all final products. This implies that GMOs or unauthorized grain must be avoided at each and every part of the supply chain. For this purpose, segregated supply chains use both prevention and remediation. Prevention of admixtures requires re-engineering of the agricultural production process (e.g. through geographic and temporal isolation of production, minimum allowable distances between fields, buffers, border rows and other physical barriers that can reduce the incidence of cross-pollination from neighbouring crops etc.); as well as of storage processing and distribution processes (e.g. through use of meticulous cleaning or use of dedicated equipment and facilities). In addition to prevention, segregated supply chains use remediation when admixtures occur despite preventive measures. Through repeated testing they seek to identify accidental admixtures thereby isolating unauthorized grain before entering the segregated stream or redirecting commingled lots back to the commodity supply chain.

Changes in supply chain operations to prevent admixtures as well as testing and remediation involve additional costs, beyond those incurred for commodities. A number of factors can influence their relative size but the most significant driver of segregation costs and the overall chance of success of segregated systems, however, is the tolerance level set for unwanted GMO material.

Segregation costs increase as tolerances decrease. The rigor with which segregation procedures are designed and implemented depends mostly on the allowable "margin of error" which is defined by the tolerance levels for unwanted or unauthorized commodities. Segregated supply chains with low tolerances imply strict measures designed to prevent even the presence of traces, additional testing and greater amounts of product failures (Kalaitzandonakes and Magnier, 2004). Beyond certain levels, as tolerances diminish segregation costs increase exponentially (Kalaitzandonakes and Magnier, 2004, 2006). For instance, Kalaitzandonakes and Magnier 2006 have estimated the incremental costs associated

1 In some occasions small amounts of biotech crops that have not been authorized for production or trade have been found in the food supply chain and, in some cases, have led to trade disruptions (Carter and Smith 2005; Li et al., 2010; Lin et al. 2003; Schmitz et al. 2004, 2005).

with reducing tolerances from 1% -0.1% in maize seed production to be, on average, 5% - 68% higher than those in seed production following standard practices.

Segregation and Zero Tolerance

Under zero or near zero tolerance, the relevant commodity trade between countries could cease (Kalaitzandonakes and Kaufman, 2011; Magnier et al., 2009) as perfect segregation of non-GMOs or authorized and unauthorized biotech events cannot be consistently achieved. Under zero tolerance there are also higher failure risks and costs. Failure risks correspond to the chance that segregated supplies considered free of unwanted GMOs test positive at some part of the supply chain. The closer to the final product the failure is discovered, the higher the failure costs are likely to be.

When segregated trade is not feasible or is too costly, the bilateral trade between the two countries may be suspended (Kalaitzandonakes et al, 2010). The incremental costs associated with the use of segregated systems or with the disruption of trade define, in large part, the economic impacts of low tolerances and such impacts can be quite variable depending on underlying supply and demand conditions. For instance, Kalaitzandonakes et al., 2010 estimated the relative impacts of potential trade disruptions in maize and soybean commodities between the EU and one or more of its trading partners due to zero tolerance policies for unapproved biotech events. They found that such tolerance policies could cause price increases 5%-24% over commodity maize and more than 210% increases over soybean commodity prices. Similarly large effects are reported in related studies (e.g. Philippidis, 2010).

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Socio-economic considerations of GM crops in the context of the Cartagena Protocol on Biosafety-CBD

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The novelty and lack of familiarity of new applications from genetic engineering in the 1970s and 1980s induced the scientific and regulatory communities to design and implement assessment procedures examining the environmental safety of these technologies. The biosafety protocols were mostly based on those used in agriculture and other economic sectors. The 2000 Cartagena Protocol on Biosafety (CPB), a supplement to the Convention of Biological Diversity, incorporated many of these principles especially in its Annex 3. The main focus of the CPB on environmental safety and transboundary movements was later expanded in practice and through different addendums to the CPB to include food/feed safety and cultivation decisions for commercialization.

The CPB became operational amongst the countries that signed the agreement in 2003. The CPB has been a major factor in triggering the creation of national and, in some cases, regional regulatory systems that occasionally extend beyond the fundamental requirements included in the CPB. The evolution of the CPB and national/regional measures has had an impact on public and private sector policies, and R&D innovation management, especially on those countries who are Parties to the Protocol. Its main objective is "to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements" (CPB, Article 1, p.3).

Article 26.1 of the CPB (See Box 1) reaffirmed countries' sovereign rights to implement protective and decision measures, subject to their own international obligations. Article 26.1 reiterated the freedom that countries had to put in place (or not) any measure to assess the potential socio-economic impact in their jurisdiction. Discussions have begun about the potential inclusion of socio-economic considerations into biosafety decision making, especially amongst some countries Party to the CPB. Many developing countries are seeking guidance in terms of conceptualizing what socio-economic considerations mean in their own context, and to design and implement appropriate measures intended to conduct such assessments.

Biosafety regulatory systems may consider safety and efficacy in their assessment of new technologies. A safety assessment, be it for environmental or food/feed safety, involves the prevention of introducing a harmful technology to the environment or public health. In turn, efficacy relates to preventing the release of technologies that do not work as intended or those which may not be addressing important societal needs. Most biosafety regulatory systems consider only the safety of a candidate technology under review, although they may consider efficacy if this has an impact on safety. These functions are usually considered by policy makers when designing biosafety regulatory systems.

Biosafety regulatory system design considers the trade-offs and the options related to democratic societies' inherent right to know about science, technology and innovation and the freedom to choose or to operate. Freedom of choice includes those of consumers to consume, but should also include those of producers to produce. Similarly, the freedom to operate should cover those of public and private sector producing goods that may benefit society. Finding a mutual point of convergence between these freedoms and rights involves negotiations between different societal stakeholders and actors to choose the best outcome.

Regulatory design needs to consider the possibility that a biosafety assessment can reach the correct decision or that it can commit errors either by approving an unsafe technology or rejecting a safe technology. The possibility of committing Type I or II errors makes the need for a robust biosafety system even greater. Regulatory designers need to bear in mind that costly regulatory processes may also be costly to reverse. To avoid the latter issues where possible, biosafety and other types of regulatory systems have based their assessments on science. Biosafety assessment procedures are a systematic and logical approach for the assessment of biosafety issues including environmental and food/feed considerations deemed important by society. In fact, most biosafety regulatory systems globally have their science-based approach in common. Most of the variations in biosafety implementation occur depending on the degree to which policy or political issues are considered in the final decision. Furthermore, most biosafety systems consider a set of graduated steps which attempt to improve knowledge about a candidate technology; they use familiarity and accumulated knowledge, and learning through new testing, which permits progression to the next step, culminating in their deliberate release to the environment as a commercialized product.

SEC and the Cartagena Protocol on Biosafety and laws and regulations

The inclusion of socio-economic considerations into biotechnology and/or biosafety decision making has been driven by Article 26.1 of the Cartagena Protocol on Biosafety and/or national laws and regulations. These policy instruments respond to society's need to know about novel technologies that may be deployed for use by farmers. As can be seen in Box 1, Article 26.1 of the Cartagena Protocol on Biosafety introduces the possibility that when deciding to permit the importation of LMOs or under the purview of national laws or regulations countries may consider socio-economic factors in their decision. This article reaffirms existing nations' sovereign rights, although subject to international agreements. Furthermore, the scope and potential impact parameters to be included in such an assessment are limited to those arising from the potential impact on indigenous and local communities affected by the use or introduction of an LMO. Article 26.1 in a sense establishes a voluntary floor in which the competent authority is bounded in their assessment procedures.

Box 1. Article 26 of the Cartagena Protocol on Biosafety

SOCIO-ECONOMIC CONSIDERATIONS

1. The Parties, in reaching a decision on import under this Protocol or under its domestic measures implementing the Protocol, may take into account, consistent with their international obligations, socio-economic considerations arising from the impact of living modified organisms on the conservation and sustainable use of biological diversity, especially with regard to the value of biological diversity to indigenous and local communities.

2. The Parties are encouraged to cooperate on research and information exchange on any socio economic impacts of living modified organisms, especially on indigenous and local communities.

Source: Cartagena Protocol on Biosafety as part of the Convention on Biodiversity

Many countries around the world have chosen to go beyond the issues described in Article 26.1 by introducing for example social, ethical, philosophical and aesthetical considerations into their decision making. Furthermore, countries have chosen many different alternatives in terms of the scope, triggers, implementing agencies, time and stage of implementation, and have decided upon decision making rules.

Socio-economic assessments in a biosafety regulatory process

The assessment of socio-economic considerations (SEC) is the result of society's need to investigate the potential impacts of technology adoption to reduce negative outcomes and in many cases satisfy intellectual curiosity. Nevertheless, socio-economic assessments conducted under a biosafety regulatory process need to clearly differentiate themselves from purely academic and intellectual exercises. This is due to the fact that at the end of a regulatory process the decision maker will reach a binding decision authorizing or rejecting the technology under review. They may also withdraw an authorization after a post-release review. Furthermore, SEC assessments are subject to time limits and to conventional issues and limitations that most regulatory processes are likely to face, including whether the assessment is for approval or for post-release monitoring purposes.

An SEC assessment done before the technology is released (an ex ante review) will have different implications and issues than that used to assess the technology after release (an ex post assessment). From a methodological point of view, an *ex ante* assessment will necessarily be based on projections and assumptions. The range of methods will be quite limited in comparison to an ex post assessment due to the fact that it the assessment is carried out without observing the technology being put into practice. In the latter, research limitations include time to complete research, budgets and the complexity of the questions.

An SEC assessor is usually an expert who uses scientific procedures, especially in an ex ante assessment, but who has also to use creativity in addressing the limitations in the analysis. In essence, the SEC assessor has to subjectively address the assumptions about the model, parameters and data limitations that may be used in the assessment. In some cases, the SEC assessor may have access to primary data can be used to define the current status of technology use and impact, society's welfare and to define some of the potential variations in the production or management process due to the LMO intervention. The potential range of assessment possibilities are usually contained in a national biosafety framework which delineates the biosafety system structure and process. Design decisions need to be carefully thought out as they may have profound effects in terms of science, technology and innovation outcomes and performance, as well as, the potential outcomes that may affect the different stakeholders in society.

Practical considerations and options for implementation

Biosafety regulatory designers and decision makers have many issues and options to consider when designing the biosafety systems' structure and implementation procedures. Countries need to decide whether the inclusion process will be voluntary or mandatory, and what the scope of the assessment will be, ranging from a stricter interpretation of Article 26.1 or one that considers broader aspects. The country needs to decide when to require the submission of an SEC assessment study, what issues are to be assessed and the questions that will need to be answered. Furthermore, the biosafety regulatory system will need to specify who will do the assessment (consultants, developers or specialized units within government) and what decision making rules and standards will guide the decision making.

The inclusion of socio-economic considerations will have to follow – and contribute to- those attributes that define a functional biosafety system partially based on Jaffe (2005). Attributes include transparency, feasibility, fairness, cost and time efficiency, the assessment hurdle proportional to the technology risk, support to the CPB objectives and process predictability. Inclusion of SEC will unequivocally increase the cost of compliance with biosafety regulations, and in some cases may also increase the time needed to complete the assessments. The cost of compliance may not be as relevant in affecting net benefits to society as the regulatory delays. In a ceteris paribus exercise Bayer, Norton and Falck-Zepeda (2010) showed that regulatory delays as little as three years can negatively affect returns to investments in these technologies. The cost of compliance may be relevant though for the public sector and those developing biotechnologies in crops and traits of interest for developing countries. R&D organizations may have difficulty paying for an SEC assessment on top of the biosafety and R&D necessary to bring this technology to farmers; furthermore they may lack the necessary means to address some of the particularities of an LMO assessment.

The SEC assessment process may also generate more, and in some cases improved knowledge about the technology and its impact. Thus, competent authorities are left with the task of examining the trade-offs between gaining more knowledge that can improve decision making thus helping to avoid costly mistakes, and the process' impacts on producer benefits and to innovation and R&D investments (See Wesseler and Ansink 2010).

Concluding comment

The assessment of socio-economic considerations and its inclusion in biosafety regulatory decision making systems need careful review. It is prudent for countries to carefully review and explain what the rationale is behind such an inclusion, even if they have already made the decision through the approval of national measures such as laws and regulations. This review needs to consider the feasibility of proposed assessments, recognizing that it may not be feasible to assess every socio-economic consideration especially in an ex ante framework. The discussion on the inclusion of socio-economic considerations as part of biosafety decision making needs to also consider all the costs, benefits and risks of inclusion and non-inclusion as is customarily done in a Regulatory Impact Assessment process. Finally the review and discussions need to clearly avoid a process without clear decision making rules and standards and other attributes that separate a well-defined process from a "black box" full of uncertainties, one which will clearly not be a functional regulatory process.

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Socioeconomic assessment: a requirement for authorisation for cultivation of GM crops in Argentina

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By the end of the 1990s, Argentina had implemented an export impact assessment stage, which became an integral part of the genetically modified (GM) crops' approval procedure. For several years, the authorization for the commercial release of a genetically modified plant organism was granted by the Secretary of Agriculture, Livestock and Fisheries based on three independent expert opinions prepared by two consultant agencies and a National Directorate of State of the Secretariat of Agriculture, Livestock, Fisheries and Food: an environmental risk evaluation, a food and feed safety assessment and an analysis of the potential impacts on Argentina's international trade. Although these three expert opinions constituted stages which must be completed in order for a commercialization permit to be granted to a given GMO, in all cases they were simply recommendations and, as such, not binding for the Secretary's final decision.

The report on the potential impacts on Argentina's international trade referred to the international market of the product concerned and the regulatory status in the main markets, in order to determine the consequences which the commercial release of the GM crop, whose authorization has been applied for, might have for the international trade of Argentina. It considered the situation of trade competitors, potential markets, the relative importance of the crop in the existing trade with the different countries of destination, and the share of these imports in their supply.

As from the late 1990s, the so-called "mirror policy" was put in place and, therefore, the final decision on GMO assessment was based on a technical analysis and a political decision. The "mirror policy" execution generally followed the EU approval patterns, taken as the main benchmark, in terms of minimizing impacts on future exports. In the case of soybean events, the importance of soybeans and soybean oil sales also required that close attention be paid to approvals granted in India and China, since the European Union is a major buyer, specifically of soybean meal for animal feed.

The commercial opinion, unlike other assessments, usually established a "waiting period", prior to the final approval, since the nature of export market analysis may implicitly define the postponement of the approval decision. This is so because, when the cause for the risk in trading a GM material disappeared since the latter was approved in the country of destination, the opinion changed automatically from unfavourable into favourable. The nature of this opinion is different from the others because this is not a toxicity or environmental impact problem. Clearly, if it were no one would allow such "mobility" in decision making.

The commercial assessment stage thus became the key to executing the "mirror policy", and only in a couple of situations was the word "disruption" heard in connection with such a policy. These situations were cases in which Argentina anticipated the decision made by a buyer country, even though the commercial report had somehow foreseen the imminent event approval.

Doing the follow-up on the procedures within the Argentine regulatory system, it can be concluded that, in almost every case, there was a favourable technical opinion as to the approval of certain events concerning food safety and environmental risk assessment; the final approval being subject to the commercial opinion, which became the third stage of the authorization process, and resulted in two significant conclusions. The first one is that, in the Argentine system, the speed of event approval was greater than in most of importing markets, since a prior technical opinion was issued first, and then there was a wait for the commercial approval. The second one is that agility in the regulatory system, counteracted by caution in order not to incur a commercial problem, generally delayed the final decision.

In fact, the time spent at the stage of commercial analysis was "virtual" since the required preliminary studies for issuing an opinion did not usually take more than 1 or 2 months. However, no final opinion was generally issued until it could be verified that any potential trading restriction had been removed.

Considering approval times in Argentina, it can be estimated that there is a period of approximately one or two years between the stages of the food safety or environmental impact assessment, as the case may be, and the final regulatory approval. Therefore, such a period would be equivalent to the virtual time attributable to the commercial analysis.

At present, there are some additional considerations on the scene. When the regulatory system became operative in Argentina, events were simple, the number of submissions was small, and the regulatory situation in the world was still in its infancy. Within such a context, the introduction of the commercial stage was perceived by some actors as an element delaying event approvals.

Nowadays, with some changes in place, the system evolved to a higher institutional degree, and grew in some regulatory aspects; but essentially, events became more complex, and they increased in number. All this shapes a scenario where the "commercial" approval instance is absolutely embedded in the regulatory process.

In the process of approving a new GM material, subject to considering potential conflicts in trade matters, the final stage entails the resolution of opposing interests between growers, seed companies, exporters, and the government itself. In some circumstances, exporters' interests prevail because it is a priority for exporters not to alter the essential characteristics of their business, which could undoubtedly be complicated by the introduction of an unapproved new material in their destination markets.

For several years, Argentina closely followed the approvals granted by the European Union and, in recent years, those given by India and China, as reference models for its own approvals. But recently, albeit informally, Argentina has been paying attention to progress made by Brazil, as a competitor country in many sectors.

Within the GMO regulatory systems, the regulated matter is the outcome of scientific and technological processes that are at the forefront of their field. GMO regulatory systems' requirements and procedures do not always include already proven advances in the field of know-how, and faced with the latest developments, it is necessary to make periodic and expeditious reviews of effective regulations, and without necessarily involving a complete amendment to such rules. Instead, there should be a specific review of cases in point. In that sense, during 2011 an in-depth study employing a participatory process to assess and propose an update on legal and regulatory aspects was developed, in order to give a renewed momentum to the Argentine regulatory system.

Beyond regulations and regulated matter, one may consider another aspect of the Argentine system, which was based on its position as a net exporting country, namely the internalization of potential trade problems. This generally developed into one of the main causes for approval delays, since it was the government itself that subordinated the final approval decision to the disappearance of market risks. Without discussing the importance of trade information or the necessary caution vis-à-vis potential problems, in the sphere of administrative acts, a clear separation of food safety and environmental risk evaluations from market-related analysis was recently introduced.

The analysis of impacts on production and commercialization resulting from the introduction into the market of a GM crop evolved introducing not only potential losses but also possible gains.

The next step should be to reinforce monitoring in relation to markets and their future evolution, as well as market performance vis-à-vis approvals for new events. This will allow the prediction of scenarios, and not only a recommendation for caution when faced with a potential problem; i.e. the ability to act strategically in the case of a trade policy involving local technology developments. Another role of the observation on trade and regulatory aspects consists of seeking enhanced diversification of export destinations, by adding promotion policies that may make them attractive for exporters, through specific mechanisms such as tax or financing incentives.

Liability, Compensation, Redress in Case of Admixture: Legal Issues

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Traditionally, and still today (though often forgotten), the loss lies where it falls, and therefore remains with the victim unless there are compelling reasons to shift it onto somebody else.

The laws of delict offer such reasons, but not in a uniform way if compared across Europe. After all, each country has its own distinct tort law system, some even more than one. While there may not be radical differences when it comes to fundamentals of liability, the distinct features of each legal system, even if seemingly only a matter of detail at first sight, may still lead to different case outcomes.

Already the notion of damage itself is not so uniformly understood after all. One of the prime differences between European jurisdictions concerns what is called "pure economic loss", which is a reduction of the victim's assets without any primary trigger of a more traditional harm. The lost profits of a conventional or organic farmer who can no longer sell her crops as non-GM (assuming for the time being that there is at least some financial bonus attached thereto) are not a consequence of some harm to her field or plants, at least arguably so. Not all countries are prepared, however, to indemnify such a pure economic loss in the absence of very specific further conditions. Another problem in this context particularly relevant in the GMO context is whether mere fear of future harm is per se already compensable, which some jurisdictions confirm and others deny.

Uncertainties of causation are also treated differently throughout Europe, starting already with dissimilarities in procedural law. The degree of likelihood to be proven to the judge in theory varies from "more likely than not" in some countries to "almost certainty" in others. At least traditionally, surpassing this threshold means full compensation to the claimant despite an up to 49% probability that it was not the defendant after all that caused her damage. Only few jurisdictions so far consider to split the loss according to the respective degrees of likelihood.

The notion of fault is linked to the required standard of care, and the outcome of the case depends upon who has to prove a deviation therefrom. Good farming practices as laid down in coexistence legislation contribute to identifying such proper conduct. Some countries have introduced liabilities irrespective of fault, or at least with a presumption of fault that can hardly be rebutted.

As far as liability for harm to the environment as such is concerned, the so-called Environmental Liability Directive primarily foresees administrative law consequences for harm to biodiversity. However, some member states have either at the occasion of implementing this Directive or even before introduced tort law rules governing harm to the environment, mostly foreseeing strict or at least rather strict rules based upon the polluter pays principle and covering also secondary losses to individuals as a consequence of harm to the environment.

The differences mentioned so far mostly concern tort law as a whole and are not peculiar to the biotechnology arena. However, there they are overlapped with differing regulatory backgrounds as already indicated. Yet another layer that comes into play are the policy objectives behind all these rules, and also in this respect no unanimous accord can so far be found in Europe.

Insurance can pool risks not only of individual liability, but also of primary losses sustained by the victims themselves, and thereby distribute the burden among all those participating in and contributing to the pool. Arguably, insurers can handle claims more efficiently than some complex court procedure would. One downside to this tempting loss-spreading mechanism, however, is the lack of risk awareness among those concerned. GM farmers, for example, may not see that there is residual risk of loss even if they abide by all rules. Also, the differences between and the difficulties of tort laws are obviously not resolved by insurance, which merely builds upon these. The most obvious problem at the moment, however, is the lack of supply on the market: Insurers still seem to be reluctant to offer products that would cater the needs of GM farmers, be it due to lack of data that would allow them to calculate the risk and therefore the premia, be it due to uncertainties in the law that remain.

Compensation funds could step in as long as the insurance industry is unwilling and/or unprepared to offer solutions. Some countries have already introduced such models, though – again – with quite some distinct features each. Such funds could be tailor-made to the peculiar needs of those addressed, and claims handling could be rather efficient because one would expect experts to administer such a fund. However, states are obviously not wiser than insurance companies when it comes to calculating the risk. This is why compensation funds – including those already set up – are threatened by unpredicted developments which currently seem to prevent insurers from stepping in. Also, one has to ask why a state should set up a more or less complex compensation scheme for such a peculiar risk as the economic loss resulting from gene flow as long as there are other – more general – risks that would deserve more attention, if only from a statistical point of view.

Undoubtedly hence, there are significant dissimilarities to be found in the laws of the European countries, which obviously have an effect on the way potential claims would be handled and resolved. The general attitude of a jurisdiction vis-à-vis GM farming clearly leaves a mark on how these countries deal with losses thereby caused.

Still, at this point in time it is at least dubious whether harmonization in this field is feasible and/or desirable. As long as significant differences between tort laws as a whole remain, it does not seem to make sense to impose a specific uniform solution for such a unique problem that does not evidently deserve special treatment.

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Innovation and liability in biotechnology: transnational and comparative perspectives

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Liability Cases in North America

Where tolerances for unintended GM content are low and include regulatory penalties, non-adopters face liability exposure for costly recalls and the spread of such contamination to the other farms or the food chain. Having paid a claim for a rejected shipment or recall of food, the non-GM farmer or food company may be left to seek remedies if the causal agent can be isolated and the company responsible sued. These seed impurity and unintended commingling issues can lead to significant liability in jurisdictions where applicable laws impose strict liability for the mere presence of biotech crop DNA in a non-GM crop or food products.

The US has had two situations in which the courts reported decisions adjudicating legal liability arising from an unapproved biotech crop commingling with commercial agricultural crops. StarLink was a transgenic corn approved for animal feed and ethanol production, but not approved for human food (Uchtmann, 2002). Contaminated corn products, such as taco shells, were then withdrawn from sale. Many companies, including grain handlers, farmers, food processors and retailers then successfully looked to the developer-patent owner, Adventis CropScience (now Bayer CropScience), for compensation. The numerous filings were consolidated into a single class action lawsuit in the United States Federal Court for the Northern District of Illinois alleging that crops and grain were unmarketable as food under adulteration standards due to the addition of an unapproved substance.

In the legal proceedings that followed, the trial judge ultimately ruled that plaintiffs who could prove that unapproved StarLink had physically contaminated their crop or stored grain had viable legal claims in negligence, private nuisance and public nuisance. After these rulings, the class action plaintiffs entered into a settlement agreement. Adventis agreed to provide $110 million in funding to allow those adversely affected by StarLink corn to be remunerated.

In 2006, trace amounts of an unapproved GM event were detected in US rice exports to Europe. In what has become known as LL601 rice, the widespread presence of this variety resulted in an announcement from the EU on August 20th, 2006, that Europe would not accept further rice shipments from the US (Li et al., 2010). The German food producer, Rickmers Reismüehle GMBH (Rickmers), sued two Arkansas defendants—the large grower co-operative Riceland Foods and the Producers Rice Mill—alleging that shipments to the company contained unapproved genetically engineered rice in breach of several contracts. Riceland Foods and the Producers Rice Mill turned to the developer of the rice variety, Bayer CropScience for an explanation, as well as compensation. As is noted by Kershen (2009), after a 14-month investigation by the USDA as to how this commingling occurred, no conclusive proof exists. In the spring of 2011, the court awarded Riceland Foods $136.8 million.

Over 1,000 other lawsuits have been launched against Bayer CropScience in this case, as the court rejected a class action lawsuit (Redick and Endres, 2009). The authors note that some reports indicate that over 6,000 lawsuits have been filed. The lawsuits sought compensation for ruined crops and for depressed international markets for America rice imports. In December of 2009, the first of these cases to be settled was decided with the first two farmers receiving settlements. One farmer received an award of $1.95 million, while the second received $53,000.

In the summer of 2011, Bayer offer $750 million to settle all of the producer lawsuits related to the LL601 rice case. This settlement is based on one condition, that being that 85% of the total rice acres planted between 2006 and 2010, have to participate (Endres and Johnson, 2011). Producers are to be compensated on a per acre basis.

Liability Regulation in Europe

Europe has been predisposed towards the integration of the Precautionary Principle into many of their regulatory and liability frameworks pertaining to agricultural biotechnology. Much of the rationale for this approach is based on previous food safety failures that have been experienced across the continent. As a result, Europe's approach towards a liability framework has differed greatly from the North American experience. While the presence of liability and compensation schemes are common across Europe, this section will focus its attention on two of the most prominent schemes—that being the liability regimes in place in Denmark and Germany.

Denmark

On 9 June 2004, Queen Margrethe II of Denmark gave royal assent to an act entitled The Growing etc. of Genetically Modified Crops (Denmark, 2004). With this royal assent, Denmark became the first European country to enact legislation regulating the coexistence of conventional, organic and transgenic agriculture.

In the regulatory sections of the Act, the Minister of Food, Agriculture and Fisheries is given significant discretion to promulgate administrative rules fleshing out the statutory provisions relating to the growing, handling, sale and transportation of biotech crops. To ensure that any GM crop production is tightly regulated by the State, the Minister may require that any Danish producer wishing to grow a GM crop to obtain a license prior to planting (Denmark, 2004). The specifications of the licenses may entail that the intending producer, at the producer's own cost, has to participate in and pass an education course on coexistence between GM crops, conventional crops and organic crops. The intent of this licensing scheme is to ensure that the Ministry has a known record of all transgenic producers within Denmark. The Danish regulatory system does not allow the unlicensed production of GM crops. In addition to a production license, the Minister may require any Danish producer intending to grow a GM crop to notify the owners and users of neighbouring fields of this intent (Denmark, 2004). The transgenic producer may also be required to notify owners of the vehicles, machines, equipment and storage the transgenic producer has or will use in growing, transporting and storing the crop.

In an attempt to recover part, or all, of the costs the Act stipulates that all producers planting a transgenic crop are required to pay 100 Danish kroner per hectare for every year that a transgenic crop is seeded into a compensation scheme (Denmark, 2004). This fee is in addition to any cost that the producer would have to pay to have access to the technology from the seed companies.

In light of the per hectare fee that transgenic farmers must pay to grow transgenic crops and fund the compensation scheme, it is not clear if Danish farmers will plant GM crops. The European Commission has approved this compensation scheme for a period of five years as a way of successful introducing transgenic agriculture to Denmark (European Commission, 2005). However, the fee is functionally a tax on producing transgenic crops. From the farmers' perspective, the tax may not make it worthwhile to plant transgenic crops. This tax can be seen as part of the barrier against Danish farmers planting transgenic crops as only one farmer had registered to produce such crops by the end of 2007 (New Scientist, 2005).

Taxing GM crops is not a successful way of introduction. Gylling (2010) notes that while over 300 Danish farmers have taken the training course on how to grow GM crops, there is not a single acre of GM crop production occurring at present in Denmark. The conclusion that can be reached is the forcing GM crop adopters to fund a liability compensation scheme is such a substantial barrier to the adoption of the technology that not a single trained or untrained Danish farmer is willing to bear the burden of this tax and consider planting GM crops.

Germany

To conform German law to EU laws (European Commission, 1990), Germany passed an act to Regulate Genetic Engineering (GenTG) (Germany, 1993). In 2004, in response to more recent EU laws relating to agricultural biotechnology (European Commission, 2001), Germany amended its GenTG by adding new provisions regarding legal liability (Germany, 2004).

In the 1993 version of the GenTG, Part V of the law included five sections on Provisions for Liability. These five sections were left unchanged by the 2004 amendments and remain a part of the present German law on genetic engineering. Section 32(1) Liability imposes civil liability upon operators for the death, injury, impairment of health or property damage of other persons resulting from the properties of a genetically engineered organism. Section 32(2) adopts joint and several liability whereby in the case of multiple users of GM each person is obliged to compensate for the full amount of the damage. Section 32(7) provides that liability for damage to property extends to impairment of nature or landscape for which the party damaged expends funds in restoration of the prior natural or landscaped state.

Section 3(9) Definitions defines "operator" to include those who establish a genetic engineering installation, perform genetic engineering operations, release or place on the market genetically modified organisms without authorization under the GenTG. When the Section 3(9) definition of operator is taken into account, it becomes clear that Section 32 Liability exists only for those involved with transgenic organisms through laboratory or confined experiments, field testing or deliberate introduction into the environment without authorization. Moreover, the damage for which compensation exists under Section 32 is direct, physical damage to the life, health or property of another person. When an operator is found liable for the direct, physical damage under Section 32, Section 33 places an exposure cap of 160 million German marks.

In the fall of 2011, the European Court of Justice ruled on a honey case that contained GM pollen that will likely have wide ranging potential liability implications for the future of GM crops in Europe. In 2005, a dispute arose between an amateur beekeeper, Mr. Bablok and the German State of Bavaria (Court of Justice, 2011). The corn variety MON 810 is one of the GM crop varieties that has been grown for research purposes in Germany and in 2005, the protein from this corn variety was detected in Mr. Bablok's honey. The presence of the GM proteins from the GM corn pollen resulted in the honey being unsuitable for marketing or consumption. In conjunction with four other amateur beekeepers, Mr. Bablok then brought legal action against the State of Bavaria, arguing that the State of Bavaria was responsible for the losses incurred.

The Court observed that even though GM pollen is incapable of replication or genetic material transfer it is technically an ingredient and needs to be identified as such. The Court concluded:

… products such as honey and food supplements containing such pollen constitute foodstuffs which contain ingredients produced from GMOs within the meaning of the regulation. … As regards the honey, the Court observes that pollen is not a foreign substance or an impurity, but rather a normal component of honey, with the result that it must indeed be classified as an 'ingredient'. (Court of Justice, 2011: p. 2)

Conclusions

The potential liability resulting from this decision could be substantial for Europe. The additional costs to the honey industry in having to label all kinds of plant pollen in honey will be noticeable, not to mention the trade problems that will arise when countries that have adopted GM crops attempt to export honey to the EU. The ultimate liability might be that no further GM crop field trials will be allowed in Europe as none of these crops are approved for production in Europe and it will be impossible to prevent the pollen from these field trials from ending up in honey all over Europe. When this occurs, the honey would then contain an unapproved GM event and be banned from the market, as was the case with LL601 rice. This one ruling may well spell the end of GM crops in Europe, even production of the two approved crops. If government research centres are no longer able to conduct field trials as part of the assessment process for GM crops, then the future for GM crop production in Europe is very bleak.

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Institutional/political factors that influence adoption and profitability of GM crops in South Africa

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The year 2011 was the fourteenth year since the first commercial release of a genetically modified (GM) crop in South Africa. In 1997/98 insect resistant (Bt) cotton was released for production and South Africa (SA) became the fist country in Africa where a GM crop is produced on a commercial level. Bt maize was approved for commercial production in the following year and the first plantings of Bt white maize in 2001/02 established SA as the first GM subsistence crop producer in the world. Herbicide tolerance events for maize, soy beans and cotton as well as stacked (Bt+HT) combinations have since been approved for commercial production. In 2010 GM maize covered more than 70 percent of SA's total maize area, HT soy beans covered more than 80 percent of the total soy area and GM cotton covered close to 90 percent of the total cotton area. Based on farm-level impacts over the adoption period up to 2008, it has been estimated that adoption of GM maize, cotton and soy beans directly added more than 500 million US$ to South African farm income (Brookes and Barfoot, 2010).

Institutional support – policy and regulation

Agriculture is a fundamental sector in the South African economy with a relatively small contribution to GDP but with substantial employment and multiplier effects. South Africa has a dualistic agricultural sector with commercial (large-scale) farmers producing the bulk of national produce, insuring food security in South Africa and to an extent in Southern Africa. The commercial agricultural sector went through a process of deregulation and liberalisation in the early 1990s and currently government support to commercial agriculture is limited to regulation and the only direct intervention is disaster relief assistance. The smallholder sector consists of subsistence farmers, smallholder surplus producers and emerging farmers. A large number of these farmers are situated in the former homeland areas where infrastructure and agricultural support services are still underdeveloped and lacking. Government interventions focus on supporting and developing these previously disadvantaged areas and farmers and to integrate these farmers into existing and novel produce value chains.

The South African Committee for Genetic Experimentation (SAGENE) was formed in 1979 by public and private scientists to monitor and advise the National Department of Agriculture and industry on the responsible development and use of biotechnology and GMOs through the provision of guidelines and the approval of research centres and projects. SAGENE gained statutory status in 1992 as national advisory committee on modern biotechnology and the approval for the commercial release of Bt cotton and maize was done under the guidelines of SAGENE. These guidelines and procedures remained the cornerstone of the biosafety framework until South Africa's GMO Act no 15 of 1997 was approved by Parliament in June 1997 and entered into force in November 1999 when the regulations were published. Under the Act, the

GMO Registrar forwards submitted applications that comply with the provisions of the Act to the Advisory Committee, which replaced SAGENE. Successful applications are recommended to the decision making body, the Executive Council, which includes officials of eight key Ministries including the Departments of Agriculture, Health, Environment & Tourism, Trade & Industry, Labour, and Science & Technology. The GMO Act and resulting regulations have been amended a number of times, mainly to bring it in line with international guidelines (Cartagena Protocol) and other national legislation.

The South African Government has identified biotechnology as a strategic industry with potential to grow the economy through more efficient industrial processes, innovative products and improved food security and health care through development of vaccines, diagnostics and treatments (Cloete et al., 2006) as is apparent from the National Biotechnology Strategy (2001) and the draft Research, Development and Innovation Strategy to Strengthen the Bioeconomy (2011). By creating a facilitating and enabling environment for a scientific and balanced consideration and regulation of agricultural GM technologies, the South African government has given farmers the option to utilise the new approved technologies. Through the Department of Science and Technology's Public Understanding of Biotechnology (PUB) programme government also make an effort to ensure a clear understanding of the scientific principles, related issues and potential of biotechnology and its applications in society through information in the media and schools as well as through public debate.

Technology triumph but institutional failure

However, the South African Makhathini Flats experience (Gouse et al., 2005) emphasises the cliché that no technology is introduced in a vacuum and more specifically that a production technology, GM or otherwise, generally cannot overcome institutional limitations (low prices or failed markets). Adoption of Bt cotton by smallholder farmers on the Flats was rapid, increasing to close to 90 percent within 5 years. This impressive adoption rate was attributed to the substantial yield increases and insecticide savings of early adopters but also to the institutional setup of the cotton production system on the Makhathini Flats. In a vertically integrated, contract farming or out-grower production system that is common to most African cotton producing countries one, geographically demarcated, cotton ginnery or company supply production inputs on credit and farmer support through extension services, with the understanding (contractual agreement) that farmers deliver their cotton to the specific gin by the end of the season. The input cost and possibly interest and admin fee is subtracted and farmers are paid the remainder.

This system worked well on the Makhathini Flats for a couple of years and the ginning company had a loan recovery rate of close to 90 percent. However a number of consecutive seasons with floods and droughts resulted in a large share of the rain fed cotton farmers not being able to repay production loans. This situation was exacerbated by a low international cotton price caused to a large extent by increased production in especially India and China.

During the 2001/02 cotton production season a new cotton company erected its gin right next to the existing company's depot on the Flats, and not having incurred any admin or extension service expenses, offered farmers a slightly higher price for their seed cotton. Most farmers defaulted on their production loans with the first company and the company and the Land Bank of South Africa, who supplied the credit facility, lost a significant amount of money. In the next season (2002/03) no credit was made available and cotton production on the Flats collapsed. Despite some efforts by the Provincial Government and the new cotton gin to revive smallholder cotton production on the Flats production levels remained low – mainly due to low profitability levels linked to the prevailing low cotton price.

Smallholder farmers in SA struggle to control bollworms on cotton due to limited insecticide, labour, clean spraying water and equipment. Smallholder farmers on the Flats benefited from the new GM insect control technology but due to adverse climatic conditions, institutional failure (ginning company competition) and low cotton prices, the welfare gain was short lived. Though cotton production has decreased significantly in SA (large and small-scale farmers), the farmers that still produce cotton plant GM cotton and with higher world cotton prices projected for the 2011/12 season, cotton planting estimations are up.

GM subsistence crop

Maize is the most important field crop in SA and annually covers an estimated 30 percent of the total arable land. Maize serves as staple food for the majority of the South African population and also as the main feed grain for livestock. Large-scale commercial farmers and agricultural companies produce the bulk of SA's maize crop while smallholder and subsistence farmers produce less than 5 percent of the national maize output. GM maize's high adoption level (in the presence of various high yielding conventional varieties) is indicative of how high commercial farmers value the GM traits (Bt and HT). However, adoption of these technologies by smallholder farmers is still minimal.

It is estimated that only about 10 500 of the more than 40 000 smallholders who regularly buy hybrid maize from the three major seed companies in SA, planted GM seed in 2007/08. The smallholder GM maize area covered about 33 700 hectares. Considering that there are an estimated 240 000 small-scale farmers in South Africa and more than 2 million subsistence farmers, it is clear that GM maize adoption by smallholders is still minimal. As the majority of these smallholder farmers plant small plots (most less than 0.5 ha) on dry land, rainfall is in most cases the determining factor in whether a surplus is produced.

On the production side smallholder grain production is constrained by small plots, land ownership issues (communal land), lacking support services (extension, inputs, credit) and limited labour (high levels of immigration to urban areas and a high HIV/Aids prevalence). On the marketing side geographical separation from large markets, and limited storage and transport infrastructure adds to transaction costs, reducing profitability of grain production.

These factors play a role in a smallholders' input investment decision and on his/her maize production motivation. In SA where maize flour is always available in the shops and where government social grants ensure at least a minimum income level for the elderly and poor families with children, a failed maize crop usually do not mean starvation like in most other African countries. Additionally, government social grants have enabled some smallholders to invest in inputs like fertiliser, hybrid maize, GM maize and herbicides and grant payout days have created a small but cash market for grain sales to the community.

Smallholder farmers' motivation for producing maize differ with some hoping to sell grain for profit, others only wishing to supply in a couple of months' household maize flour demand and others only planting a couple of rows of maize for consumption as green (fresh) maize. Based on research findings (Gouse, forthcoming), it can be expected that smallholders' GM adoption decision will depend on their maize production motivation but also their production limitations. In areas with high stem borer infestation, smallholders have adopted Bt maize continuously for a number of seasons and farmers with smaller households and slightly higher off-farm income (less family labour or time to spend on the farm) have adopted HT maize. Due to a high level of heterogeneity in the smallholder group, it can be expected that GM maize adoption rates will probably not reach the levels seen with commercial farmers.

Conclusion

While the efficacy of Bt and HT GM technologies have been proved in South Africa (large and small-scale farmers) it is the institutional arrangements that determine adoption, profitability and ultimately a sustainable positive welfare impact.

Reviewing Science behind Consumer Attitudes, Willingness-to-Pay

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1. Introduction

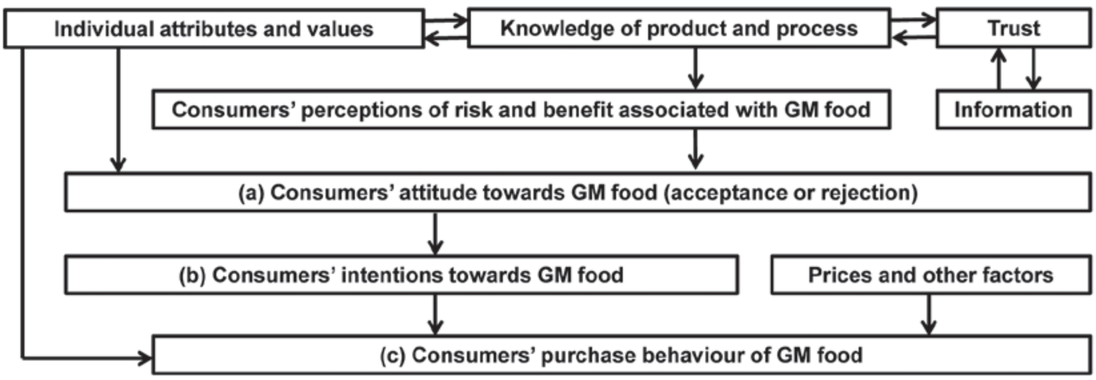
The development of genetically modified (GM) food has been a matter of considerable interest and worldwide public controversy. However, in order to fully understand the controversy and draft appropriate public policy, the demand for these goods needs to be understood as well. No matter how technologically superior GM crops may be to the farmer, they will not have an impact if consumers are not willing to accept them.

A growing body of literature on consumers' attitudes and purchasing intentions and behaviour related to GM food is available, reviewed by several authors (Lusk *et al.*, 2005; Costa-Font *et al.*, 2008; Smale *et al.*, 2009; De Groote, 2011). From this literature, two main findings emerge: (i) consumers in developed countries consistently show a preference for non-GM food over GM food, with this preference being particularly strong in Europe; and (ii) in developing countries, a lower awareness of GM food and a more positive attitude is observed until the point that positive price premiums for GM food are recorded.

Costa-Font *et al.* (2008) provide an overall picture of the consumer decision process in relation to GM food (Figure 1). They conclude that consumer attitudes towards GM food are driven by three main dimensions: (i) risks and benefit perceptions associated with GM food; (ii) individual values such as environmentalism, conservationism, materialism and equity; and (iii) knowledge and its relation with values and trust on the different sources of information.

Smale *et al.* (2009) further distinguish two main bodies of literature, indicated in Figure 1: (a) surveys designed to elicit the attitudes of consumers toward products made with GM crops; and (b) stated and (c)

Figure 1. An explanatory process of GM food acceptance (Costa-Font et al., 2008)



revealed preference methods to estimate the hypothetical and real price premiums consumers are willing to pay for products that are free of GM ingredients. In this paper, we focus on the second body of research. In particular, we embed the methods that have been used in that literature in a framework which can be used to interpret willingness-to-pay (WTP) estimates for GM food across studies.

2. Stated versus revealed preference methods

Lusk *et al*. (2005) provide a meta-analysis of stated and revealed evidence of GM food preferences based on 25 studies and 57 valuations. The evidence confirms the general findings described above and further suggests that WTP for GM food is determined by (i) the characteristics of the food being valued, (ii) the characteristics of the sample of consumers studied, and (iii) the method for eliciting consumers' valuation. Acceptance of GM ingredients in products increased from meat products to oil products and products with tangible benefits such as increased nutrition. By including several variables into their meta-analysis related to the method of value elicitation, the authors generate interesting information on the method's influence on WTP. Their sample includes several types of conjoint analysis, contingent valuation and experimental auctions. An important variable is whether the valuation task was hypothetical or non-hypothetical. For instance, all contingent valuation studies included in the analysis were hypothetical and all auctions were non-hypothetical, as were a few of the conjoint-choice experiment valuations.

One of the primary reasons experimental auctions have emerged as a useful tool in new product development research is the increasing recognition of the drawbacks associated with hypothetical WTP and purchase intention questions. There is now a wealth of evidence that people tend to significantly overstate the amount they are willing to pay for goods in a hypothetical setting as compared to when real purchases are made (see the literature reviews cited by Lusk, 2010). The existence of a so-called positive "hypothetical bias" on WTP also surfaces in Lusk *et al*.'s (2005) meta-analysis.

3. General framework: Balance between control and context

The issues discussed above can be understood when embedded in a larger framework of the balance between *control* and *context*. *Control* means the researcher has control over the environment such that no unmeasured external force drives choices. That is, confounding of cause and effect is eliminated. What separates an experimental auction from other auctions is the attention given to control. Context implies that subjects have some contextual cues about why their decision might matter in a bigger world.

Traditional sensory and marketing research methods attempt to estimate *ex ante* WTP for new food products by constructing hypothetical markets. The growing popularity of explicit experimental methods arises in large part from the potential for control, i.e. it enables constructing the proper counterfactual (Harrison and List, 2004). Experimental auctions exploit the middle ground between total control and total context by *creating* the missing market (Lusk and Shogren, 2007). In experimental auctions, people bid to buy *real* products using *real* money in a setting employing rules that provide incentives for people to truthfully reveal their value for each product for sale. Whereas responses to conjoint or purchase intention questions provide an indication of stated preferences (decision stage b in Figure 1), bids in experimental auctions are revealed preferences (stage c) and are interpreted as the maximum amount people are willing to pay for the new good (Lusk, 2010).

Recent experimental work has begun to move from laboratory settings to the field to elicit values at the point of purchase (Harrison and List, 2004). By moving the auction to more familiar territory, such as grocery store or mall, one might gain some context in return for giving up some control as the population of interest is directly intercepted (Lusk, 2010). Lusk *et al*.'s (2005) meta-analysis suggests that such increase in context substantially reduces WTP for non-GM food. On the other hand, increasing the role of the researcher as an intermediary between the experiment and the individual substantially boosts WTP which may suggest that the gains in control may be partially offset by observation bias and social desirability bias. This bias may further increase if one moves from individual to group auctions (Demont *et al*., in press).

4. Discussion and research implications

The growing body of literature on consumers' WTP for GM food seems to be unanimous on two main findings. The stronger consumer opposition towards GM food in Europe seems to be supported by cross-Atlantic studies using the same research method (e.g. experimental auctions, see Lusk *et al*., 2006). In contrast, there is much less single-method cross-country evidence in support of the second hypothesis, i.e. that consumers in developing countries support GM food much more than consumers in developed countries. Most authors ascribe this outcome in part to government policies, and some to cultural and political history (Smale *et al*., 2009). However, the available evidence does not enable excluding the possibility that the differences may have been partly generated by the *endogeneity* of the research method and the context. Two arguments may support this hypothesis.

First, if the research context constrains the researcher to rely on a different research method, WTP may be measured systematically differently in developing countries. Lower education levels and higher degrees of illiteracy, for instance, may increase the role of the mediator, with the concomitant risk of introducing observation bias, and move the valuation study away from the context.

Secondly, experimental methods in food valuation are an emerging research field in developing country contexts (De Groote, 2011). Since the publication of Lusk *et al*.'s (2005) meta-analysis—which included only one developing country (China)—the evidence on consumers' WTP for GM food in developing countries has dramatically grown. Smale *et al*.'s (2009) review identifies 33 of such studies of which 12 report WTP estimates for GM food in Asia. Further evidence from Africa is reported by De Groote (2011). However, most studies in developing countries rely on hypothetical methods and WTP estimates may have been partly inflated due to hypothetical bias.

Both arguments illustrate the crucial role of "reviewing the science behind consumer attitudes" in the interpretation of WTP for GM food across studies. Depending on the research question at hand, conducting valuation work in a field setting may be beneficial if this is the environment in which consumers will actually be making food purchases (Lusk *et al*., 2005). However, for some research questions such as testing the impact of information on WTP, more control is needed. Hence, the ultimate challenge for the experimenter will be to find the optimal balance between context and control in designing food valuation experiments such that the latter are truly demand-revealing and informative to public policy makers.

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Human Health Implications of GMOs: A Focus on Bt Maize and Mycotoxin Reduction

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In discussions of genetically modified organisms (GMOs), the potential impacts to human health are of critical concern. GMOs have the potential to cause both beneficial and adverse health effects in humans. A reasonable health concern to consider is that any time a novel gene is successfully introduced into a food crop, that crop will produce a novel protein. Proteins, while rarely toxic or carcinogenic, can be allergenic. Therefore, care must be taken to introduce genes that would not produce proteins that are known allergens or likely to be allergenic in humans. In the United States of America, for example, proteins produced by any transgenic crop likely to appear in the market are subjected to a variety of tests to determine their allergenic potential: whether the organism from which the transgene is taken causes allergic reactions in humans, whether there are homologies in amino acid sequence in the novel protein to known allergens in an allergen databank, and the digestibility of the protein in simulated gastric conditions.

However, perhaps of greater importance are the potential health benefits that can accrue from the cultivation and consumption of certain GMOs, particularly in less developed countries. Aside from the (currently) more theoretical GMOs that would contain essential micronutrients or withstand drought conditions, even the GMOs that are most commonly planted worldwide today could provide a variety of health benefits. For example, transgenic herbicide-tolerant crops and pest-protected crops could reduce the amount of labor needed in the field, which could then be devoted to aquaculture or other pursuits that would allow for greater dietary variety. These GM crops are also potentially helpful in communities where HIV prevalence is sufficiently high that agricultural workers are limited by their health status in how much energy can be devoted to agricultural labor. Additionally, pest-protected crops such as the Bt (*Bacillus thuringiensis*) crops would drastically reduce the amount of topical pesticide required in agricultural fields. Planting Bt crops could reduce workers' risks of excessive exposures to topical pesticides, which can be toxic or carcinogenic in humans and harmful as well to wildlife.

Also of great importance is the phenomenon that Bt maize has been shown to have significantly lower *mycotoxin* levels than non-Bt maize isolines. Mycotoxins are secondary metabolites of fungi that colonize food crops; these toxins can cause a variety of adverse health effects in humans. The most common classes of mycotoxins in maize worldwide include aflatoxins, fumonisins, and deoxynivalenol (DON or vomitoxin). Table 1 lists the adverse human and animal health effects associated with each of these mycotoxins. In parentheses under the name of each toxin are the fungi that most commonly produce the toxins.

The adverse effects of these foodborne mycotoxins in global health is real and measurable. Liu and Wu (2010) estimated that 25,200-155,000 liver cancer deaths worldwide are caused by dietary aflatoxin each year. Other studies have linked aflatoxin with childhood growth impairment (Gong et al. 2002) and

Table 1. Adverse human and animal health effects associated with three classes of mycotoxins in maize. Source: Wu et al. (2011).

	Human health effects	Animal health effects
Aflatoxins (Aspergillus flavus, A. parasiticus)	Liver cancer (hepatocellular carcinoma) Acute aflatoxicosis Immune suppression Stunted growth in children	Liver tumors Immune suppression Reduced weight gain and productivity Lower eggshell quality in poultry
Fumonisins (Fusarium verticillioides, F. proliferatum)	Esophageal cancer Neural tube defects in babies	Equine leukoencephalomalacia Porcine pulmonary edema Immune suppression Reduced weight gain and productivity
DON (Fusarium graminearum, F. culmorum)	Gastrointestinal disorders Immune dysfunction	Gastrointestinal disorders Immune dysfunction Reduced weight gain and productivity

immunosuppression (Jolly et al. 2008). Fumonisin has been implicated in increased risk of neural tube defects in babies (Missmer et al. 2006) and esophageal cancer (Marasas 1996). DON has been implicated in immune and gastrointestinal dysfunction (Bondy and Pestka 2000).

Bt maize has been shown in a variety of studies across the world to have significantly lower mycotoxin levels than non-Bt isolines. The field evidence is reviewed in Wu (2007). The earliest studies on this topic were done in Iowa, showing lower levels of fumonisin in multiple Bt maize events (Munkvold et al. 1999). The results were then replicated in multiple countries and continents worldwide (Bakan et al. 2002, de la Campa et al. 2005). Likewise, DON levels have been shown to be significantly lower in Bt maize than non-Bt isolines in different continents (Aulrich et al. 2001, Schaafsma et al. 2002). Aflatoxin reduction in Bt maize has been less consistent, in part because until recently, the types of insect pests controlled by Bt maize were not usually those implicated in *Aspergillus* infection. However, recently approved Bt maize events may have improved efficacy in reducing aflatoxin contamination (Odvody and Chilcutt 2007).

If Bt maize were planted in the parts of the world where mycotoxin contamination were a serious threat to human health, then there could be appreciable health benefits in terms of reducing dietary mycotoxins. However, many of the most severe foodborne mycotoxin problems are in Asia and Africa (Liu and Wu 2010), where very few nations permit commercialization of Bt maize. Therefore, in order for these health benefits of Bt maize to be fully realized, a first step is in regulatory changes that would permit for transgenic crops with proven benefits to be allowed for commercialization where they are currently not permitted.

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Do European consumers buy GM foods?

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Evaluating the responses of prospective consumers to novel and prospective technologies is always difficult, especially when the goods or services are not actually available for them to try. It is even more testing when the technology and its products are constantly denigrated as dangerous and worthless with opponents claiming as a consequence that "there is no demand".

Is there ever much of a "demand" for something which does not exist, for which there are no specific pictures, sounds or tastes, or which cannot be inspected by the potential purchaser? It has been said that Sony invented the Walkman, not because members of the public were banging on their doors demanding a portable music player, but because the co-chairman of Sony wanted to be able to listen to operas during his frequent aeroplane journeys and one of the company's audio-division engineers had a bright idea. Sony created the product – and thereby also created the demand.

The CONSUMERCHOICE project was conceived precisely because of the difficulties of measuring shoppers' potential behaviour. By the time of the project's conception there had been many polls of consumer opinion conducted, it must be stressed, against a raucous background of vigorous antagonism on the part of opposing campaigners together with a rich flow of frightening newspaper headlines and stories. Such polls tended to be based on "what would you do if?"; "*if* there were GM-products in the grocery stores, would you buy them?" Such questions were not infrequently posed in rather graphic terms: "would you eat Frankenstein foods?" or with a picture of a syringe needle inserted into an innocent tomato. The responses were no surprise but nor were they reliable evidence of intent or behaviour.

Nevertheless, throughout a decade or more of this type of "market surveys", crude as they were, a rather different picture was emerging here and there from focus groups and from in-depth studies. The outcome varied from country to country: my own detailed experience is, specifically, the situation in the UK and I cannot easily judge how typical it might be for other Member States.

It was always clear that the opposition to GM-foods, though loud, was by no means universal. A common finding was that a comparatively small proportion of the populace was indeed vigorously antipathetic but was often neatly balanced by a roughly similar proportion who proclaimed themselves to be rather enthusiastic in the light of *their* perceived benefits of the new technology. Together, these two groups formed about a quarter of the total. The remainder was often divided into another quarter or so who were vaguely against GM (for reasons often not clearly defined) but did little or nothing to avoid them; the remainder, nearly half the total population, seemed not to care one way or the other.

Opinion polls notwithstanding, there had been little attempt to gauge actual consumer behaviour with respect to their purchasing GM-products. There had been various "experiments" to test public reaction. One of them was carried out in Germany in April 2004 (and was one of the factors encouraging the development of the CONSUMERCHOICE proposal). In a supermarket, bread from an allegedly GM-wheat was mixed with the bulk supply, and the resulting bread given a fake GM label. A 500-gram loaf was offered for € 0.29, less than a third of the standard price. Potential customers were observed via a hidden camera. At first the reactions were ones of surprise – some people appeared to have little confidence in the bread. Indeed, many potential customers regarded the "GM-bread" as unsafe but others were not deterred – the low price was effective. Of 30 allegedly GM-loaves on display, 22 were sold on the day of the trial, four times the amount of that type of bread sold on other days.

The second trial took place in a snack-bar: normal potato chips ("French fries") were labelled as "GM-chips" and sold at half price. The results confirmed the first test: even though some people, no doubt hungry for the chips, had doubts and rejected the "GM"-product, 27 portions were sold actually sold compared with only one of the conventional variety. Interesting though those episodes might have been – and there have been others in which conventional, GM- and "organic" products have been sold side-by-side – it is difficult to know to what extent the customers realised that this exercise in Germany was some sort of experiment and acted accordingly.

Thus, in December 2003, when the idea of CONSUMERCHOICE first arose in discussion, the situation remained unclear, confused and likely to differ in the various Member States of the EU. In the usual run of opinion polls we feared that the customers felt they were being asked via a questionnaire or a pollster about something which was in some way not normal and not part of their everyday activity. Such a perception might well prompt the respondent to think unusually carefully about this question because of hidden implications which might be embedded within it. Our objective was therefore to assess the *actions* of shoppers in what was for each individual an entirely familiar shopping environment rather than asking questions which would have been bound to alert their attention that something about the whole matter was distinctly odd.

There were clearly difficulties in developing such an approach. In those countries in which GM-products were (and still are) on sale, our hovering around the appropriate shelves in grocery stores (how many such stores?) waiting for customers to buy (how many customers?) the products (how many products should be involved?) was an impossible experimental approach except on a very small scale. Moreover, in Member States in which no GM-products were available there was no way in which the behaviour of customers could be assessed in the normal environment when presented with a choice of such foods.

We therefore adopted a variety of other methods. As a start, and for all the ten countries in the study, we surveyed the public influences on the populace with respect to GM-technology, particularly the roles and attitudes of the media and of the political establishment.

In Member States in which GM-products were on sale, we were able to undertake a more meaningful study:

1. finding out which products were on sale, how widely they were offered, and whether they remained available for a protracted period and hence were actually being purchased; we reasoned that products which few people bought would not for long remain on the shelves of competitive food stores;

2. undertaking in some countries a bar code analysis of all the products (including labelled GM-foods) actually purchased by consumers who belonged to a panel of shoppers reporting via a bar code scanner in their own homes all their purchases to a company analysing the data. Those comprehensive

data were compared with the responses (albeit on an anonymous basis) of the very same individuals who had made the purchases to questions about whether they would or would not buy GM-foods. We could thus match answers given by individual shoppers to "what would you do if?" questions with what those same individuals actually bought as part of their normal food purchases.

3. for Poland and the UK we were able to conduct polls of residents of those countries who had visited Canada or the US (in both of which GM-foods are widespread yet in neither are they labelled), asking whether they knew of the prevalence of GM foods in North America, whether they were concerned and, if so, what steps they had taken to avoid them.

4. In just one case (in Germany), consumers who had chosen to purchase milk labelled as "GM-free" were asked individually after their purchases why they had bought that particular milk rather than some other brand not carrying such a label.

5. In almost all the Member States participating in the study we conducted focus group discussions in order to explore in some detail the range of attitudes people showed towards the GM question together with the arguments they gave in support of their positions.

It was impossible to come to hard and fast deductions applicable to all the circumstances in all the countries involved in the two-year study from 2006-2008. But one conclusion was indeed rather clear. The project set out to determine whether European consumers bought GM-foods. It is always dangerous to give simple answers to complex questions; any answer to this one will certainly not encompass all European consumers. Our inquiries have shown much variety in the ten Member States of our study but nevertheless, in a broad sense, the answer is:

"Yes – when they have the opportunity"

Global pipeline of GM crops by 2015: implications for socio-economic assessment

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Socio-economic assessment of GM crops has been performed most frequently in "1st generation crops" (i.e. those with an agronomic trait that benefit farmers) in a limited number of countries. However, increasingly attention turns to "2nd generation crops" (i.e. GMOs with a quality trait that offer benefits to consumers or crop users in the industry). When considering the need for new methodologies for impact assessment of GM crops, an essential step is therefore to look forward to the commercial pipeline of these products: While agronomic benefits can be assessed easily using conventional techniques of agricultural economics, such new crops may require new methods.

In a recent paper (Stein and Rodríguez-Cerezo, 2010) we showed that currently there are around 30 commercial GM events that are cultivated worldwide, yet the forecast is that by 2015 there will be over 120: for soybeans, currently only 1 GM event is available, but this number is predicted to increase to 17 different events; maize events are expected to increase from 9 to 24, rapeseed events from 4 to 8 and cotton events from 12 to 27. In the case of rice where currently no commercial events are cultivated, the prediction is that by 2015 as many as 15 GM events could be grown if the political and regulatory environment develops favourably; potatoes also are predicted to move from no current cultivation to 8 events, and other, minor crops are predicted to grow from 7 events currently marketed to 23 events by 2015.

Moreover, individual GM events can easily be combined by conventional crossings by plant breeders to generate new varieties with multiple desirable traits. Such "stacking" of (authorised) events is already common in maize and cotton, but it may be a challenge for methodologies aiming to understand socio-economic impacts of a particular agronomic or quality trait.

More importantly, though, is that not only new GM crops like rice and potatoes, are foreseen to be commercialised soon, but also a limited number of **new traits**. In addition to currently **commercialised agronomic traits** if insect resistance, herbicide tolerance and virus resistance, the pipeline predicts that by 2015 also **new commercial traits will be available covering crop composition and abiotic stress tolerance** (mainly optimised oil and starch content, improved nutrient profiles, and drought tolerance).

While drought tolerance is also an agronomic trait whose impact can be measured via higher yields, quality traits have no direct benefits for farmers (and may even come with a yield penalty or cause more work if the crops have to be segregated). However, crops with quality traits have a higher value for their

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buyers and, if this is captured through higher prices, the economic assessment of such specialty crops is also straightforward as the higher prices farmers receive for their crop can be balanced with any changes in yield or differences in input costs.

One exception is for instance where crops with quality traits are developed without a profit motivation and for target populations that lack purchasing power to generate a market demand that reflects the benefit they derive from consuming these crops. A case in point is e.g. "Golden Rice" – rice that has been engineered in the context of a humanitarian project to produce provitamin A in its kernels. Vitamin A deficiency imposes a heavy burden on public health in many developing countries with predominantly rice-eating populations where the poor cannot afford a more balanced diet containing fruit, vegetables and animal products. To carry out socio-economic assessments of such "biofortified" crops, researchers adapted methodologies from health economics to quantify the (non-monetary) health benefit that results from the consumption of these crops, based on which further economic analyses were possible (Stein et al. 2005, Stein et al. 2008).

Another situation where the assessment of new GM crop traits may pose challenges is when the cultivation and use of these crops produces externalities that are not captured in the price of these crops. For instance, the cultivation of new GM crops could result in a lower impact on the environment compared to conventional crops (e.g. because of lower greenhouse gas emissions). To the extent that these benefits do not affect the agronomic properties of the crops and do not command a market premium, they will not be reflected in conventional economic assessments. From a societal point of view, such benefits can be very relevant, though. Therefore the idea of carrying out life-cycle assessments (LCAs) has gained increasing popularity over the last years. In such a comprehensive analysis all costs and benefits "from cradle to grave" are considered and the impact of product on overall welfare is evaluated.

In conclusion, methodologies used in socio economic impact studies on GM crops need to take into account future evolution of the types of crops released (including multiple stacks and 2nd generation, consumer oriented crops).

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Wester corn rootworm in Europe: where uncertainty meets heterogenity

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The socioeconomic impact of GM crops on European agriculture and their inclusion in the authorisation process has been the subject of lively debate lately. The basis for this debate can be found in the limited experience with GM crops in the EU. This scarcity of data leads to uncertainty during assessment and requires the use of assumptions. Hence, ex ante impact assessments of GM crops should acknowledge the importance of uncertainty to more accurately represent the reliability of results. The invasion of Europe by the alien species Diabrotica virgifera virgifera LeConte or Western corn rootworm (WCR) offers an interesting case study to present a possible methodology to cope with two types of uncertainty facing the researcher: (i) uncertainty surrounding the technology and (ii) variability in the characteristics of farmers.

The first outbreak of WCR in Europe occurred during the early 1990s [1]. The Central European outbreak now extends over 11 countries, from Austria to the Ukraine and from Southern Poland to Serbia. WCR larvae damage maize by feeding on the root system, with adult beetles feeding on maize silks sometimes causing economic damage. Exogenous factors such as precipitation and the timing of damage relative to crop phenology determine the extent of yield loss, which leads to tremndous variabilty in the relation between population pressure and yield loss [2] and hence the appropriate control option. Dillen et al. [3] describe a stochastic bio-economic model to tackle this problem and assess the relative and absolute competitiveness of the following crop protection (CP) options compared to no control.

1. *No CP* is applied. The farmer implicitly assumes that the yield loss caused by the pest will be less than the cost to apply a CP and so no CP is applied.

2. *Soil insecticides*. The efficacy and consistency of soil insecticides depend on a number of factors: active ingredient, application timing because of limited persistence in the soil (about 6 weeks), leaching, physical and chemical composition of soil, and mechanical and operational aspects (see Gerber [4] for a detailed review).

3. *Seed treatment*. In this case, the active ingredient is placed directly on the seeds via a coating, thereby optimizing both spatial and temporal application while reducing management requirements. Although these products provide adequate protection under low pest population pressure, they tend to be more variable in protection than traditional soil insecticides under high pest population pressure [5-7].

4. *Crop rotation*. The univoltine beetle lays its eggs during late summer, mainly in maize fields. Eggs overwinter and hatch the next spring. Because WCR larvae cannot differentiate between the roots of plant species [8] and have limited mobility, they feed on the roots in their vicinity. However, roots of crops other than maize are inadequate food sources for WCR larvae [9], so that rotating maize with a non-host crop offers a practical solution to limit pest population growth and control damage.

5. *Bt maize*. The crop expresses a coleopteran-specific insecticidal toxin in its roots because its genome contains genes from the soil bacterium *Bacillus thuringiensis* (Bt). Most farmers adopt Bt varieties as substitutes for soil insecticides. Bt maize gives systemic protection to WCR and, because the toxin is expressed in the roots, its performance is less likely to be affected by environmental conditions, planting time, soil conditions or calibration of machinery [10].

The economic model assumes a counterfactual uninfested yield level and simulates a probability density function (PDF) of possible yields under different CP options, $y(CP)$, calibrated on field trial data from the USA [11]:

$$y(CP) = y_{base}(1 + d(CP)) . \qquad (1)$$

Here y_{base} is the base (uninfested) yield and $d(CP)$ the percentage of this base yield lost under the different CP options. The distribution of final yields feeds a partial budgeting model:

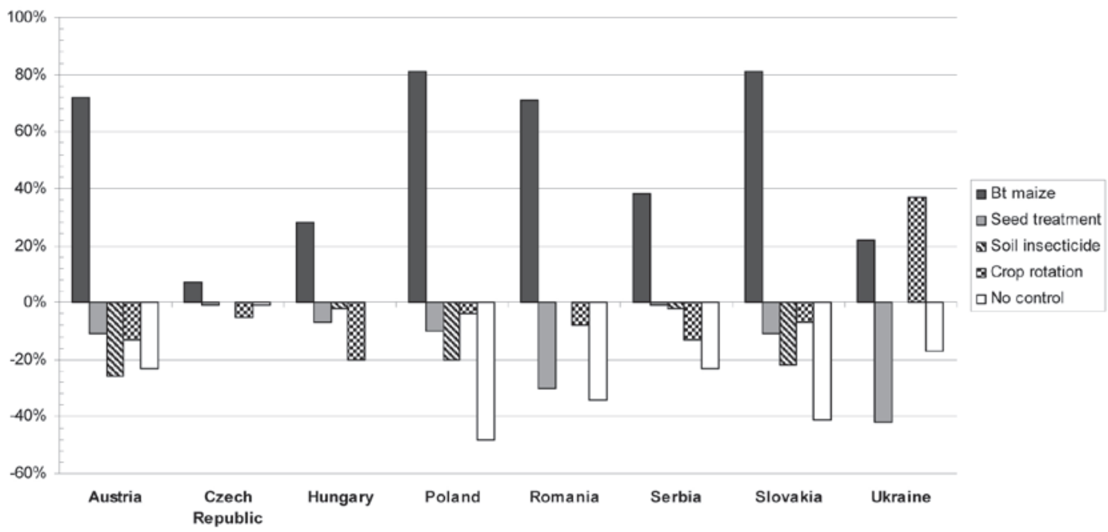
$$\pi(CP) = p_{maize}\, y(CP) - k(CP) . \qquad (2)$$

Here $\pi(CP)$ is the value of a particular CP options, p_{maize} the market price for harvested maize and $k(CP)$ the cost of the chosen CP option. As farmers have heterogeneous characteristics stemming from the differences in soil, climate, managerial capacities, access to markets, labour use, plot size, etc., their yield potentials and costs differ. Hence both y_{base} and $k(CP)$ follow PDFs to capture the heterogeneous outcome for farmers for each CP option.

The resulting stochastic bio-economic model uses Monte Carlo simulation to empirically generate the PDF representing the value of each CP option compared to no CP. The detailed results for Hungary can be found in Dillen et al. [3] and for Austria, Czech Republic, Poland, Romania, Serbia, Slovakia and the Ukraine, refer to Dillen et al. [12]. The results show that depending on the country and the type of farmer, the average net benefit of Bt maize compared to the next best CP options ranges between €23/ha and €58.5/ha in grain maize.

Besides these averages, the stochastic nature of the model allows further analysis of the simulation results. We examine the outcome for each individual Monte Carlo iteration to determine the optimal CP option for that iteration, given the set of parameters. Based on this analysis, we predict the potential adoption rates for the different CP technologies. In this paper we focus on how the deregulation of Bt maize would alter the presence of different CP in the agricultural landscape. Figure 1 presents the absolute changes in the proportion of the maize area under different CP options after the introduction of Bt maize.

Figure 1 implies that the availability of Bt maize would significantly decrease the area of maize not protected against WCR. For instance in Poland, we estimate that 48% of the area planted with maize, currently unprotected, would receive some sort of CP if Bt maize were deregulated. Moreover, we notice a large decrease in the maize area treated with chemical CP options, especially with soil insecticides



(e.g., Austria, Poland, Slovakia). This change is a valuable side effect, as the most commonly used active ingredient (tefluthrin) has negative effects on some non-target organisms [13]. Another interesting result is that Bt maize does not seem to decrease substantially the area under crop rotation. The largest decrease is found in Hungary, where 20% of the area under crop rotation would be converted to Bt maize. Hence, Bt maize as such does not shift farmers to more monoculture as is sometimes suggested.

This short paper demonstrates three important points:

- Applying a stochastic approach to ex ante impact assessments to represent heterogeneity and uncertainty can deepen the insights provided by model results and avoid focusing on a hypothetical average farmer that does not exist.
- The WCR invasion of Europe is a real economic threat to European maize production.
- The deregulation of Bt maize would provide a useful addition to the farmer's toolbox that has a high average value for maize areas infested with WCR and can also decrease dependency on chemical insecticides.

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The future of GM rice and the possible social and economic impact

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In the last assessment of the pipeline of GM rice projects and prospective products (Stein and Rodríguez-Cerezo. 2009 Technical Report EUR 23486 EN), it was anticipated that up to 15 GM traits could be commercialized by 2015, and that these would come almost exclusively from Asia and that many also would be developed by public national centers. This assessment took into account those events or traits in the commercial and regulatory pipeline (5 events, including LLRICE62, in the US only) and those proposed to be in the advanced R&D pipeline (14 traits).

Reassessing the progress since then: one of the commercial pipeline events, Bt63, has received a biosafety certificate from the Chinese regulatory authority, but has yet to complete the varietal approval process (the validity of the biosafety certificate is until Aug, 17, 2014); two other events in China, KMD1 and Xa21, are no longer under active development in the country, and the other event, B827, had only a short-lived release in Iran. Of those in the advanced R&D pipeline, *Golden Rice1* has been replaced with *Golden Rice2*, and many of the biotic and abiotic stress traits listed in the report have not advanced greatly. An exception can be found in the multiyear and event selection trials for new lepidopteran resistance materials in China and India. As will be discussed below, a number of these events could still be released by 2015.

In both China and India, there has been emerging government scrutiny of the release of GM traits in food crops, and the reticence to approve the products may be highlighted by the unfortunate handling of the Bt eggplant product in India: unfounded claims of health concerns with the Bt protein - one of the world's most studied proteins and present in millions of hectares of maize and cotton grown annually in Brazil, Argentina, South Africa, and North America - has led to a delay in the final release of the product, in spite of obtaining biosafety clearance from the then final authority, the Genetic Engineering Approval Committee. The situation in India is also complicated by the fact that the new Biotechnology Regulatory Act of India and the Seed Law have still not been enacted. However, in neither India nor China, the apparent reticence has not slowed the advanced development of GM rice products, with noticeable increases in their field testing in recent seasons.

Agricultural biotechnology is a strategic industry for China and for now all GM rice development is being driven by mostly public sector institutions, but some of which have licensing agreements with prominent seed companies. In a recent review, Chen et al. reported on 17 advanced insect resistant GM rice projects, some of which also are combination traits with drought tolerance and herbicide tolerance (Chen, Shelton, and Ye, Annu. Rev. Entomol. 2011. 56:81-101 [Suppl]). Some of these traits are being developed in hybrid parents and in prominent varieties, suggesting a faster development path than those being developed in experimental, non-current varieties. In addition, at least one of these traits was started from more a thousand independent transformation events – a prerequisite often for the selection of a successfully performing commercial and "regulatory-ready" event.

In India, late stage regulatory trials of Bt rice have been conducted by Maharashtra Hybrid Seeds Company (Mahyco). These efforts are closely followed by multilocation trials of additional Bt rice events and other traits, and some of these included event selection trials by BASF, Bayer CropScience, Pioneer Hi-Bred, and others (source: http://moef.nic.in/divisions/csurv/geac/information.html).

The Golden Rice trait incorporates novel carotenoid biosynthetic genes that are expressed exclusively in the rice endosperm and leads to the accumulation of beta carotene in this edible portion of the rice grain; beta carotene in the plant-form precursor to vitamin A. A *Golden Rice2* (Paine *et al.*, 2005 Nat Biotechnol. 23: 482-487) event has been chosen for the project. The project has also secured additional funding from the Bill & Melinda Gates Foundation (to complement funding from the Rockefeller Foundation and the US Agency for International Development). Helen Keller International has joined the project to determine if the product will help alleviate vitamin A deficiency and if yes, to design a program to deliver the product to those most in need. It is anticipated that the regulatory dossier could be delivered to the regulators in the Philippines by as early as 2013 (www.irri.org/goldenrice).

A number of the leading GM rice traits/products have been examined in *ex ante* studies, with the most prominent on the economic and other advantages of Bt rice in China. One of these, conducted by Jikun HUANG and collaborators, compared the expected performance of Bt rice, in multiyear and multilocation field trials, to those of Bt cotton, already a success in China, because the Bt rice product was expected to have similar changes in seed cost, yield, labor costs, and pesticide reductions. These studies had also modelled the effect of a subsequent potential loss of the small rice export market from China to probably sensitive markets (e.g. Japan, Republic of Korea). These analyses predicted a net internal gain for rice production from Bt rice, five years following market introduction, of a multiple of the billion $ gain for the country from the introduction of Bt cotton (Huang, Hu, Rozelle, and Pray, 2005 Science 308: 688-690; *ibid*, 2008 Econ Development and Cultural Change 241- 261). An added aspect of these studies was a self-reported reduction in pesticide poisonings by the farm families in the Bt rice trials versus non-participants; these studies are being repeated in another large scale trial and will include clinical measurements of pesticide exposure (personal communication).

The effect of Golden Rice (and other nutritionally improved GM rice traits) on health consequences in a number of countries has studied using an *ex ante* Disability Adjusted Life Years (DALYs) approach to estimate the reduction in morbidity and mortality as a result of the adoption of these traits (Stein, Sachdev, and Qaim, 2006 Nat. Biotechnol. 24: 1200-1201; De Steur *et al.*, 2010, Nat. Biotechnol. 28: 554-556). These current studies estimate that the traits would have significant impacts on the reduction of the health consequences of vitamin A deficiency and at costs often lower than those of other approaches. For Golden Rice, the existing studies were completed before the determination of the bioavailability/bioconversion rate of the beta carotene to vitamin A (more than 25% of the beta carotene in Golden Rice is converted to vitamin A in adults: Tang *et al*. 2009. Amer. J Clinical Nutr. 89:1776-83; later studies will report on related studies in children) and thus used much more pessimistic estimates of the conversion rate; plans are underway to update these *ex ante* studies.

In a rather novel valuation exercise, and one that has merited a Harvard Business School Case Study, Arcadia Biosciences is collaborating with the Ningxia Hui Autonomous Region (Ningxia) of China to establish a carbon credit methodology applicable to rice through the adoption of the GM Nitrogen Use Efficient trait developed by the company in the crop (http://hbr.org/product/arcadia-biosciences-seeds-of-change-abridged/an/711050-PDF-ENG).

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Title: International workshop on socio-economic impacts of genetically modified crops co-organised by JRC-IPTS and FAO
Workshop proceedings

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Abstract

This JRC Scientific and Technical report provides proceedings of the "International workshop on socio-economic impacts of genetically modified (GM) crops" which was co-organised by JRC-IPTS and FAO in Seville on 23-24 November 2011.

JRC-IPTS has been requested to review for policy makers the main findings of scientists active in this field world-wide in co-operation with FAO. The objective of this workshop, which was directed at socio-economic experts from the Competent Authorities of the EU Member States and staff from the EC, was to start the technical discussions between the Member States and the Commission to define factors and indicators allowing a proper capture of the impacts of GMOs in the EU.

The workshop covered the following topics:

Session 1: Adoption of GM crop varieties and socio-economic impacts on farmers
Session 2: Aggregated and global impacts of GM technology in agriculture
Session 3: Economics of segregation/coexistence of supply chains
Session 4: Socio economic impacts of GM crops: examples of use in decision-making
Session 5: Economic compensation, liability issues and institutional framework influencing adoption of GM crops
Session 6: Research on consumer attitudes, direct/indirect impacts of GM crops on consumers including health issues
Session 7: Looking forward: New GM crops in the pipeline and their possible economic and social impacts

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