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National Research Programme NRP 59 “Benefits and Risks of the Deliberate Release of Genetically Modified Plants”: Review of International Literature

Genetically Modified Crop Production: Social Sciences, Agricultural Economics, and Costs and Benefits of Coexistence

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Aim of the three literature reviews

The National Research Programme “Benefits and Risks of the Deliberate Release of Genetically Modified Plants (NRP 59)” consists of four main areas of interest:

1. Plant biotechnology and the environment
2. Social, economic and political aspects
3. Risk-assessment, risk-management and decision-making processes
4. Synthesis and overview studies

It was neither in the capacity nor in the scope of NRP 59 to duplicate the many studies on benefits and risks associated with genetically modified plants (GMP) that have been carried out in other parts of the world. On the other hand, it may be possible to distil relevant and valuable scientific data from the results of such studies that could help to shape future research and decision-making processes specifically tailored for Switzerland. In the frame of focus point IV, three overview studies were therefore compiled by members of the Steering Committeee of NRP 59 that evaluate on an international scale existing research and knowledge on topics that are of direct relevance to the central themes of NRP 59.

In the volume “*Medical issues related to genetically modified plants of relevance to Switzerland”* Karin Hoffmann-Sommergruber and Karoline Dorsch-Häsler provide an extensive overview of health-related risks and benefits of GM plants.

In the volume *“Genetically modified crop production: social sciences, agricultural economics, and costs and benefits of coexistence”,* Joachim Scholderer and Wim Verbeke assembled valuable insight obtained by screening literature databases and research/project portals, and through direct contacts with key researchers in the different areas.

In a comprehensive third volume entitled *“Synthesis and overview studies to evaluate existing research and knowledge on biological issues on GM plants of relevance to Swiss environments”*, Jeremy Sweet and Detlef Bartsch compiled information resulting from close to one thousand scientific publications relating to biological and environmental issues on GMP.

The chapters in this volume will not only be useful to a readership that is familiar with the biological, environmental, political, socio- and agro-economical aspects of GMP, it will also provide newcomers to the field with an in-depth introduction into a range of specialised topics that are relevant to this complex area.

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1. Introduction

1.1 Background

The National Research Programme (NRP) 59 is mandated to inform the Swiss Federal Council on the first relevant results generated in the context of NRP 59 in preparation for the political debate that will take place at the end of the moratorium on GM plants. As an integral part of NRP 59, Module 4 should focus on synthesis and overview studies that evaluate existing research and knowledge on topics in Modules 1 to 3.

To comply with this goal of the programme, projects have been invited to compile, analyse, and communicate what is known from existing medical/public health, ecological and social science research that has been performed in other countries and to assess to what extent these studies are relevant to Switzerland. In addition to a detailed analysis, the output of such studies should include a summary that highlights potential practical consequences for Switzerland that are of relevance to politicians and the public. By Summer 2012, a synthesis document cutting across the different research areas will be produced. The document will encompass a summary of the existing knowledge based on the evaluation of different international programmes, complemented with findings obtained so far within the context of NRP 59.

According to implementation plan, it is neither in the capacity nor in the scope of the NRP 59 to duplicate the many studies on benefits and risks associated with GM plants that have been carried out in other international programmes. However, it is possible to distil relevant and valuable scientific data from the results of studies and reports from outside Switzerland that could help shape future research and decision-making processes specifically tailored for Switzerland. The NRP 59 Steering Committee of decided to cover the field of Module 4 by launching a further call for projects or by directly mandating experienced persons with clearly focused projects over a fixed time period.

The NRP 59 Executive Office proposed that members of the Steering Committee could be mandated to compile synthesis and overview studies, principally based on research that has been performed in other countries, taking into consideration to what extent these studies are also relevant to Switzerland. The executive office suggested the following three independent synthesis and overview studies, to be conducted by members of the Steering Committee:

- Biological sciences, ecology, risk, coexistence (crop management issues)
- Social sciences, agricultural economics, and costs and benefits of coexistence
- Medical science and public health

1.2 Objectives

The objective of the research synthesis commissioned to address Topic 2 is to provide an integrative overview of existing social science research related to genetically modified plants, covering psychological, economic, and selected agricultural issues. Most of the published research has been conducted outside Switzerland. This research will be summarised in the present report, covering international science, with a particular focus on research that has been conducted in the European Union. The initial report has been supplemented with a follow-up review of the social science research that has been conducted in Switzerland, with a particular focus on the results that have been already been obtained in the NRP 59 social science projects. Many findings from international studies will not without qualification be applicable to the Swiss situation. Therefore, consultations will be held with Swiss experts before the project report will be finalised. Finally, the results of the proposed project will be integrated with the other NRP 59 Module 4 reports so that the final report can be delivered to the Swiss Federal Council.

1.3 Social Science in its Historical and Political Context

The public debate on genetically modified (GM) crops and foods has a long and complex history. In the 1970s and 1980s, the debate was mainly led among scientists themselves, with little divergence between Europe and the United States. This changed in the 1990s, when different regulatory frameworks emerged that led to a transatlantic divide (see Joly & Assouline, 2001; Levidow, Carr & Wield, 2000; Torgersen, Hampel, Bergmann-Winberg, et al., 2002). In the United States, the commercialisation of GM crops occurred relatively smoothly. In the European Union, however, a heated debate ensued between stakeholders in the second half of the 1990s, culminating in a five-year moratorium on the approval of new GM crops and foods that was lifted in 2004 (for a review of the debate, see Scholderer, 2005). Although less heated, similar debates occurred in the Asia-Pacific region in the first years of the new millennium, and are taking place in developing regions right now.

Social science research on GM crops and foods has to be understood in this context. Much of the research conducted by social scientists was politically motivated, often publicly funded through strategic research programmes similar to NRP59. Social science research on GM crops and foods began with a series of technology assessments that were started in the late 1980s. In Germany, the Office of Technology Assessment at the German Parliament began monitoring public opinion about modern biotechnology as early as 1985. The Dutch Ministry of Education and Science started in the same year with a number of small-scale qualitative studies, whilst the Ministry of Agriculture commissioned its first consumer survey in 1988. Denmark began in 1987, when the Board of Technology commissioned a panel survey on behalf of the Danish Parliament. In the UK, these political processes started substantially later. The UK Department of Trade and Industry commissioned a first research project in 1991. None of the remaining EU member states undertook comparable technology assessment exercises before 1998. The European Commission launched the Special Eurobarometer series on “Europeans and Modern Biotechnology” in 1991.

Since these early days, social science research on GM crops and foods has diversified remarkably. Whilst most of the early research understood itself as technology assessment, there was a shift in the late 1990s towards interdisciplinary consumer research. Research became more academically ambitious, much of it focusing on the psychological foundations of technology acceptance among member of the general public. Studies in this area will be the focus of the first part of the present review. Of course, traditional public opinion research still exists, and it is useful to monitor trends in “average” technology acceptance among different stakeholder groups because that has to be taken into account in political decisions. However, such trends depend crucially on the nature of the public debates in the respective countries, and findings from one country are not necessarily valid in the political context of another country. In the second part of the present review, we will therefore restrict ourselves to public opinion research that has been conducted in the political region immediately surrounding Switzerland, the European Union. Technology acceptance and public opinion have to be primarily understood as attitudes towards policies. Such attitudes do not necessarily play an important role in the evaluation of tangible consumer products, and they are not necessarily related to choices consumers make in the retail store. In the third part of the review, we will therefore focus on the influence of genetic modification as a product attribute on the actual behaviour of consumers.

1.4 Methodology

Relevant studies to be included in the present report were be identified by three means: (a) literature databases, including EconLit, ISI Web of Science, MedLine, PsycINFO, RePEc, SSRN etc., (b) research and project portals, including CORDIS, FAO, IFPRI, OECD etc., and (c) direct contacts to key researchers in the different research areas covered by the report.

2. Cognitive Representation and Evaluative Processes

Most social science research on GM crops and foods is concerned with the attitudes of people, either in their role as citizens or in their role of consumers. Contemporary psychological theory sees attitudes as temporary constructions, representing states of mind rather than traits of persons (Conrey & Smith, 2007; Schwarz, 2007). From this perspective, it makes no sense to speak somebody's "true" attitude. Rather, there are as many potential true attitudes as there are patterns of relevant memory content that can be activated. The degree to which an attitude is stable over time and in different contexts depends mainly on two factors: the nature of the concepts and the strength of the connections between them that represent an attitude in somebody's memory and reasoning, and the similarity of the contexts in which the attitude is activated.

Attitudes only tend to have a strong representation in somebody's memory when they are based on repeated direct experience with an object. When such learned associations between an object and its evaluations exist, mere confrontation with the object will automatically activate these associations, triggering an immediate affective response (Fazio, 2007). Psychologists refer to such evaluations as "implicit" attitudes. In the absence of such learned associations (or in addition to them) people may utilise other sources of evaluative knowledge to construct an evaluative response, engaging in propositional reasoning (Gawronski & Bodenhausen, 2006, 2007). In the following, we will first discuss existing evidence concerning the relative importance of associative and propositional processes in the evaluation of on gene technology and its applications. Then, we will review studies that tried to identify the content and organisation of concepts involved in propositional reasoning about on gene technology and its applications, and its complexity.

2.1 Automatic Association Activation or Propositional Reasoning?

No more than three studies have been published up until now in the literature that specifically investigated the role of automatic activation processes in evaluations of gene technology by members of the general public. However, since all of these were laboratory experiments that were conducted with university students as participants, their external validity has to be regarded as limited.

Spence and Townsend (2006) conducted a small laboratory experiment with university students in which they attempted to measure automatic associative evaluations with genetically modified foods (using the go/no-go task, GNAT). The exemplars of the category "GM foods" were "transgenic crops," "GE livestock," "GM plants," "engineered salmon," and "modified tomatoes". Three different versions of the GNAT were used. In a first, context-free version, only evaluative concepts (e.g., "good," "horrible") were presented as stimuli besides the target concepts. In a second version, concepts related to conventional food and agriculture were included (e.g., "fruit farming," "haddock"). In a third condition, concepts related to organic food and agriculture were included (e.g., "free range," "organic carrots"). Only in the context-free version, evidence for the existence of implicit evaluations was found: participants responded slightly faster when the category "GM foods" was paired with the evaluative category "pleasant" than when it was paired with "unpleasant". However, it cannot be excluded that the positive evaluations were exclusively primed by the *food* concepts that were part of the composites used as exemplars of the GM foods category (e.g., the concept "salmon" in the composite exemplar "engineered salmon"). In line with this interpretation, the effect disappeared completely when the two contextualised versions were used. Furthermore, the implicit evaluations measured by the GNAT were not significantly correlated to participants' explicit evaluations of GM foods (which had been measured by means of semantic differential scales) in any of the conditions. Spence and Townsend (2007) used the context-free version of their GNAT again as part of a larger investigation and obtained similar results as in their initial study.

Tenbült, de Vries, Dreezens, and Martijn (2008) report a related laboratory experiment, again with university students as participants. The authors used a more sensitive procedure for measuring implicit evaluations (the extrinsic affective Simon task, EAST) and only included stimuli that made no reference to foods (the exemplars used in this study were "genetic modification," "cloning," "genetic manipulation," "genetic technology," and "genetic change"). The authors measured a small but significant negative implicit evaluation of these stimuli. However, the implicit evaluation was not correlated with participants' explicit evaluations or different dimensions of attitude strength (which had been measured in terms of ambivalence, centrality, commitment, and subjective knowledge).

Taken together, the limited evidence suggests that there is no strong, associative representation of evaluations of gene technology, at least not at present, and not in the population segments (university students in the UK and the Netherlands) that constituted the participants in the studies conducted up until now. The absence of strong implicit attitudes is not exactly surprising. Implicit attitudes require repeated experience with the attitude object. Such experiences can either be made in direct interaction with the attitude object or through regular exposure to other types of evaluative information, for example in the media or in personal conversations. The absence of GM foods on European supermarket shelves and the low coverage in the media in recent years make it quite unlikely that EU citizens could have acquired enough experiences to form implicit attitudes towards gene technology or its applications.

2.2 Complexity and Organisation of Concepts Involved in Propositional Reasoning

The results reviewed in the previous section suggest that automatic, implicit affective reactions to the concept of gene technology only play a minor role when members of the general public evaluate the technology or its applications. Apparently, other forms of information are utilised in evaluative judgments about gene technology, and it appears that these judgments are formed through conscious, propositional reasoning processes. In the following, we will review a number of mainly qualitative studies that provide evidence of the content, the organisation, and the complexity of the concepts involved in such propositional reasoning processes.

Hagemann and Scholderer (2009, Study 2) investigated the complexity of laypeople's reasoning about the risks and benefits of genetically modified crops. They confronted their participants with a short, non-evaluative description of an example application (a GM potato with altered glycoalkaloid levels) and asked to state what they thought about it. On average, participants generated no more than 2.4 statements in response to this question, suggesting that the cognitive representation of gene technology and its application to food crops is sparse in most individuals. A content analysis of the responses indicated a slight dominance of negative (55%) over positive evaluations (45%). In terms of target domain, the most frequent categories were the environment (43%), human health (21%), governance issues (16%), economic issues (16%), and broader evolutionary issues (3%). When asked to elaborate on their initial statements (e.g., "health"), participants typically paraphrased or elaborated conceptually in terms of class-inclusion relationships (e.g., "human health," "animal health"). Reasoning in terms of cause-effect relationships was only rarely found among lay participants, and if so, it tended to be rather abstract (e.g., "toxins are unhealthy").

Schütz, Wiedemann and Gray (1999) investigated the degree of determinacy in laypeople's reasoning about risk and benefit. They conducted focus groups and individual face-to-face interviews, using a relatively unstructured protocol that gave participants the opportunity to reason as much as they felt inclined to about the risks and benefits of gene technology and its applications. The responses were coded according to their degree of causal determinacy. Of all statements about risk that respondents had spontaneously generated, 25% contained neither a cause nor a consequence. Instead, consumers tended to paraphrase or generate tautologies (e.g., “because it is so risky”) when asked to elaborate. Only 8% of the statements contained a causal specification of risk (mainly related to safety aspects or potential abuse). 67% of the risk statements contained a specification of the consequence, but not the cause. Most of the specified consequences were related to humans, and fewer to the environment, animal welfare, or societal issues. Substantially more benefit statements were generated during the interviews than risk statements, and they also they tended to have a higher degree of causal determinacy. Only 4% of the benefit statements contained no specifications of cause or consequence. 21% of contained a causal specification (most of them related to lower costs for producers or consumers, followed by safety benefits and better product qualities). The remaining 75% of benefit statements contained a specification of consequence, but not cause. Again, most of the consequences were related to humans, followed by economic benefits, abstract statements about health, the environment, science, and society in general.

Brüggemann and Jungermann (1998) conducted an interesting investigation of the effect of different levels of abstraction on the extremity of people’s evaluations. Besides other biotechnology applications, their stimuli included genetically modified foods. These were described to the same participants on a high level of abstraction (“gene technology”), a medium level of abstraction (“gene technology in agriculture”), and a low level of abstraction (“genetically modified tomatoes” and “genetically modified rape”), whilst identical descriptions of risks and benefits were included in the texts. The authors found that consumers’ evaluations of risks as well as benefits were significantly more extreme on higher levels of abstraction. The more concrete the descriptions became, the less extreme became consumers’ evaluations, whilst trade-off values for risk versus benefit remained constant. The results point to an attenuation effect in the concretisation process: consumers appear to form their evaluation mainly on the abstract level of the general technology, whilst, when more concrete applications of the technology are to be evaluated, mere random variation appears to be added, resulting in a process not unlike regression towards the mean.

Connor and Siegrist (2011) report a study on the relationship between the content of laypeople’s associations with the term “biotechnology” and their overall attitudes. The study was conducted in Switzerland and was part of NRP59. People who associated biotechnology with concepts like “science” and “improvement” tended to have positive overall attitudes towards agricultural biotechnology, whereas people who associated biotechnology with concepts like “environment” and “industry” tended to have negative overall attitudes towards agricultural biotechnology.

Interactive construction of beliefs

Hamstra and Feenstra (1989) were the first to conduct a detailed qualitative analysis of the beliefs that consumers construct in interactive types of settings that are typical for public engagement exercises. The design of their study consisted of focus group-like workshops, enriched with elements typically found in citizen conferences. Every workshop started with a general discussion of modern food production issues. After a while, concepts of modern food biotechnology were introduced (including genetic modification), and spontaneous reactions were elicited from the participants. After a first round of discussions, participants were invited to listen to three presentations: a speaker from a consumer organization, a speaker from a company developing GM foods, and a videotape with general background information about modern food biotechnology. After this, discussions were continued, using a group-laddering protocol to probe more deeply into consumers’ beliefs about biotechnology in general and its application in food production in particular.

From hindsight, it is interesting to note that the issues uncovered by Hamstra and Feenstra (1989) are virtually identical to those uncovered in most subsequent qualitative studies. Aspects of uncertainty figured prominently in consumers' responses, indicated by concepts like ignorance, fear, control, and trust. Also apparent in this early study was the persistent association of modern food production methods with perceived losses in terms of taste, naturalness and healthiness. Finally, a whole range of consumer policy issues was raised that are still at the centre of the public debate, including freedom of choice, labelling, the trustworthiness of regulatory institutions, and allegations of purely economic motives underlying producers' choice of ingredients and processing methods. On the other hand, participants in this study also recognised the potential of modern biotechnology to provide advances in terms of convenience, prolonged shelf-life of products, and lower prices for consumers.

Differentiation between applications

Several studies investigated whether different beliefs were associated with different target applications. Frewer, Howard and Shepherd (1997) elicited personal constructs representing genetic modification of different types of organisms from a small sample of British consumers. Modification of animals or human genetic material was associated with attributes like causing ethical concern, being unnatural, harmful, and dangerous. Modification of plants and microorganisms was more often associated with attributes like being beneficial, progressive, and necessary.

Bredahl (1999) investigated the risks and benefits that consumers associated with two concrete product examples, including beer brewed from genetically modified yeast, and yoghurt produced with the help of genetically modified starter cultures. Consumers from Denmark, Germany, Italy, and the UK participated in the study. The results of the content analysis were quite similar for the two product examples. Both for yoghurt and beer, the attribute "genetically modified" yielded more negative than positive associations. In all four countries, the focus was on beliefs relating to unhealthiness and a lack of trustworthiness. Notably, most of these associations did not relate to the particular genetic modification in the respective example product. Instead, they focused on somewhat nebulous consequences consumer perceived the general technology to have, including issues related to the integrity of nature ("harms nature", "morally wrong"), uncertainty ("unfamiliar", "cannot trust product"), the power balance between different actors in the marketplace ("only benefits producer"), and a general expectation that modern food processing methods as such would render a product unhealthy ("unwholesome and artificial").

Grunert, Lähteenmäki, Nielsen, et al. (2001) report the results of another, very detailed interview study involving consumers from Denmark, Finland, Norway and Sweden. Consumers received product descriptions of cheese, candy and salmon products representing different types of GM applications. The GM applications varied along a "psychological distance" dimension and a "what is modified" dimension, and were presented along with conventionally produced product variants. In general, consumers appeared to regard the absence of genetic modification as a value in itself and associated the use of the technology with a broad range of negative consequences, but predominantly with uncertainty and unhealthiness. Benefits of the use of GM were regarded as relevant, but could not compensate for the negative associations. In all product categories, the major distinction respondents made was between GM and non-GM products. The absence of GM was, in turn, mainly associated with safety and healthiness, whilst any kind of GM application was associated with uncertainty and unhealthiness, along with a range of other, more specific negative associations. Within the GM product variants, the "psychological distance" dimension turned out to be particularly important. In almost all cases, the average preference ranks were identical to the ranks of the products on the "psychological distance" dimension, with products where GM material was absent in the final product ranking highest, and products where the material was present and active, ranking lowest. Results concerning the other factor varied in the design, whether the GM application referred to raw material, enzyme production or microorganisms were less clear. In the cheese case, no apparent differences could be detected. In the candy case, modifying processing aids (enzyme production or microorganisms) was more acceptable than modifying the raw material. In the salmon case, modifying soybeans for use as feed was more acceptable than feed containing modified microorganisms. By design, the three products had differed in terms of the particular risks and benefits attributed to them. In none of the cases were the benefits able to compensate for the negative associations with genetic modification. However, the degree to which the benefits figured in respondents' perception varied. In the candy example in particular, relatively remote societal benefits (like benefits to the environment) and personal hedonic benefits (like a smooth taste) did not seem to be good promoters of GM acceptance, whereas a benefit combining societal relevance and personal health benefits (low calories/can be consumed by diabetics) seemed to work best, partly compensating for the negative associations.

Tenbült, De Vries, Dreezens and Martijn (2006) and Tenbült, De Vries, van Beukelen, Dreezens and Martijn (2008) investigated a related question. They confronted their participants with descriptions of GM and non-GM food products that varied in the degree of processing. The results indicated that a product that is already highly processed suffers less from being genetically modified than a product that is only minimally processed. The effects was found for different dependent variables, including acceptance, perceived naturalness, perceived healthiness, perceived necessity, and expected taste.

Complexity of belief systems

Only few studies have been reported in the literature that examined the covariation between belief statements about gene technology. Bredahl (2001) used 15 belief items in a standardised survey, constructed from the beliefs identified in a qualitative pilot investigation. The survey involved representative consumer samples from Denmark, Germany, Italy and the UK. Using principal components analysis, she explored the dimensionality of the belief data and found that two principal components were sufficient to represent the covariation between the beliefs: a risk dimension, and a benefit dimension. Saba and Vassallo (2002) used six belief statements in a representative sample of Italian consumers. Exploring the dimensionality of the belief set, they found that two principal components were sufficient to represent their data as well.

Midden, Boy, Einsiedel et al. (2002) report a factor analysis of attitude statements in the Eurobarometer (1996) data, including the altogether 24 that asked respondents to evaluate the usefulness, risk, moral acceptability, and overall support of the six prototypical biotechnology applications included in the survey (see below). Although the items were not actually belief statements but overall evaluations, the authors found a two-dimensional structure as well. The first factor comprised all evaluations of usefulness, risk, moral acceptability, and overall support, whilst the second factor comprised the risk statements. Very similar results had already been obtained by Hamstra (1991) in a similar analysis of overall evaluation data gathered from a representative sample of Dutch consumers.

The results indicate a rather low degree of complexity in consumers' beliefs, both concerning gene technology in general as well as GM foods in particular. Two dimensions were found sufficient in all studies where belief complexity was investigated. This finding does not exactly come as a surprise as European consumers simply do not have any experiences with GM foods. Furthermore, the debate in the media has largely been conducted on the level of the general technology, rather than on the level of particular products (Bauer & Bonfadelli, 2002; Gutteling, Olofsson, Fjæstad, et al., 2002). Hence, a lack of differentiation could only be expected.

2.3 Relationships to Other Socio-Political Attitudes

Attitudes towards gene technology and its applications in food and agriculture cannot be fully understood in isolation from attitudes towards other social issues. In the qualitative investigations reviewed above, it already became obvious that people tend to reason about gene technology by setting it into relation to other issues such as the environmental, technological progress in general, and the actors and institution involved in the development of technologies, the management of risk, and the production, processing, and distribution of food products to the consumer. These results are corroborated by the results of numerous surveys and experiments in which attitudes towards these issues were measured in a standardised and quantitative way.

The broadest investigation of the relationship between general socio-political attitudes and attitudes towards GM foods was conducted by Bredahl (2001) in Denmark, Germany, Italy, and the UK. In this study, consumer were asked to respond to a whole battery of attitude scales, measuring attitudes towards the environment, technology, consumer alienation from the marketplace (i.e., anti-capitalist attitudes), food neophobia (i.e. the habitual tendency to reject unfamiliar foods), subjective knowledge, as well as risk and benefit items which had been constructed on the basis of qualitative pilot research. The battery of socio-political attitudes could explain more than half of the variance in perceived risk (53%) and perceived benefit (61%), respectively, indicating a strong dependence on general attitudes.

In a way, the Bredahl (2001) study effectively synthesises converging results obtained in many smaller-scale studies. Attitudes towards environment and nature, for example, were also found to be negatively correlated to attitudes towards GM foods by Frewer, Hedderley, Howard and Shepherd (1997) and Sparks, Shepherd and Frewer (1995) in the UK, Hamstra (1995) in the Netherlands, Honkanen and Verplanken (2004) in Norway, Siegrist (1998) in Switzerland, Scholderer and Hagemann (2006) in Denmark, Søndergaard, Grunert and Scholderer (2007) in Finland, Germany and Italy. Attitudes to science and technology were also found to be positively correlated to attitudes towards GM foods by Borre (1990) and Scholderer and Hagemann (2006) in Denmark, Hamstra (1991) in the Netherlands, Sparks, Shepherd and Frewer (1994) in the UK, and Søndergaard et al (2007) in Finland, Germany and Italy.

Siegrist (2000) conducted a survey with a representative sample of Swiss consumers. In this study, he focused on the concept of social trust to explain perceived risks and benefits associated with gene technology. Social trust refers to people's willingness to rely on experts and institutions in the management of risks and technologies. He found that social trust was positively related to perceived benefit and negatively related to perceived risk. Relationships between attitudes and trust – either measured in terms of social trust or in terms of source credibility – were also found by Frewer, Scholderer and Bredahl (2003) in Denmark, Germany, Italy, and the UK, Poortinga and Pigeon (2004, 2005, 2006) in the UK, Scholderer and Hagemann (2006) in Denmark, and Søndergaard et al. (2007) in Finland, Germany and Italy, and replicated by Connor and Siegrist (2010) in Switzerland.

2.4 Attitude Change

Communication about genetically modified foods – including crops, processing aids, and the various public policy issues related to them – has been the topic of an extraordinary amount of musings and deliberations over the past two decades[1]. Considering the importance of the

[1] At the time of writing, a Google search using the query *consumer AND information AND food AND ("genetically modified" OR "genetically engineered")* yielded over 6.9 million results.

topic, surprisingly little research has been conducted on the effectiveness of different forms of communication. Up until now, no more than ten studies have been published in the scientific literature that specifically investigated the effects of communication about gene technology on consumer attitudes by means of controlled attitude change experiments. The results are rather meagre: most of these studies did not manage to find systematic attitude change effects.

Frewer, Howard and Shepherd (1998) presented consumers with a list of ten very simple messages that all stressed the benefits of GM foods. Apart from a depolarisation effect that may have simply been a consequence of regression toward the mean (the split into initially positive and negative consumers had been performed based on an unreliable measure of initial attitude), no systematic attitude change was observed. Furthermore, the authors found that perceptions of source credibility were strongly dependent on participants' initial attitudes towards GM foods. In a follow-up study, Frewer, Howard, Hedderley, and Shepherd (1999) confronted consumers with sets of similar simple messages that all stressed the benefits of GM foods, but varied in persuasiveness. The persuasiveness of the messages did not have a significant overall impact on attitudes towards realistic types of GM foods, but tended to decrease the negativity of attitudes towards unrealistic, "shocking" types of GM applications (e.g., transfer of human DNA into animals for agricultural purposes).

Scholderer and Frewer (2003) confronted consumers with realistic communications materials of three different types: (a) argumentatively balanced, general information about gene technology in food production, (b) information about the benefits of particular example products and (c) conventional product advertising. Compared to a control group where participants not been exposed to any information, none of the information groups showed any changes in attitudes in response to the communication. No polarisation or depolarisation effects were observed either. In a related study, Frewer, Scholderer and Bredahl (2003) used the same information materials, attributed to different sources, and investigated whether perceived source credibility mediated the relationship between information exposure and attitude change. The authors found no systematic attitude change effects and no mediating effects of source credibility. Rather, perceived source credibility was subject to a strong assimilation effect, corroborating the findings of Frewer et al. (1998): the degree to which a participant trusted an information source was a function of the degree to which the information attributed to that source confirmed the prior attitude of the participant.

Peters (2000) confronted his participants with four different newspaper articles and four different television features, all dealing with relatively complex issues related to gene technology. Analysis of think-aloud protocols gathered in this study showed that consumers generated substantially more negative cognitive responses than positive ones, and that the evaluative tendency in the cognitive responses was correlated to the initial attitudes of consumers. Although positive cognitive responses as such had higher effects on attitude change, the altogether higher number of negative responses neutralised this effect, resulting in an overall absence of attitude change.

Miles, Ueland and Frewer (2005) investigated whether information about improved traceability of genetically modified food ingredients through the food chain would have a positive effect on consumer attitudes towards GM foods. Participants in the traceability-information condition received a page of information about traceability of GM material and new detection methods. Participants in the no-information condition did not receive this information. However, no attitude change effect could be observed.

Søndergaard, Grunert and Scholderer (2007) examined whether media reporting featuring the process and outcomes of public participation exercises would have an impact on consumer attitudes towards industrial gene technology applications. However, the effect of such information did not differ from the effect of media reports in which traditional forms of technology assessments – with or without stakeholder involvement – were featured, and it did not depend on the institution that was conducting the participation exercise. Furthermore, all media reporting on technology assessments yielded negative attitude change effects relative to a control group that had not been exposed to any information.

Wilson, Evans, Leppard and Syrette (2004) report the results of a laboratory study in which participants were given the opportunity to access up to twelve news stories about GM crops from a stylised media portal. Although no systematic attitude change occurred, attitudes were more polarized after the information-gathering task than they had been before. Dean and Shepherd (2007) exposed their participants to *pairs* of relatively complex messages about GM foods. The messages in each pair were attributed to two different sources that were either in consensus or in conflict regarding their assessment of risk or benefit associated with GM foods. Attitude change in terms of a decrease in perceived risk was observed in response to consensus pairs of messages but not in response to conflicting pairs of messages. Attitude change in terms of an increase in perceived benefit was observed in response to both conflict and consensus pairs of messages. Although the authors did not conduct formal mediation analysis, the similarity of the findings they obtained for source credibility as the dependent variable suggest that trust may have been involved in the attitude change process, either as a mediator or subject to an assimilation effect (as observed by Frewer et al., 1998, and Frewer et al., 2003).

Qin and Brown (2007) obtained a small but significant attitude change effect in response to information material that was partially comparable to the conflict condition in the Dean and Shepherd (2007) study. The information described a specific application in depth (AquaBounty's genetically modified AquAdvantage™ salmon) and then outlined the positions of several major stakeholder groups toward the application and towards genetic engineering in general. The attitude measure taken in this study only referred to the specific application, however, hence it is uncertain as to whether the information materials also affected participants' evaluation of the technology in general.

Taken together, the results of these studies suggest that single exposure to information by means of simple mass communication techniques may not have enough persuasive power to change consumer attitudes towards gene technology. Furthermore, it appears that communication about new forms of risk assessment and management (such as public participation exercises, traceability systems) suffers from the same lack of persuasiveness as more traditional risk-benefit communication. Although the hypothesis is plausible, yet, it is not quite clear whether more complex types of information and repeated exposure will really be more effective. Increased research efforts are clearly needed here.

3. Public Opinion About Gene Technology

Numerous “opinion poll”-like surveys have been conducted on national and cross-national levels, using a variety of different example applications, question formats, and response formats. Although several authors have undertaken attempts to provide overviews (e.g., Finucane & Holup, 2005; Hamstra, 1998; Zechendorf, 1994), it is impossible to fully integrate these studies, especially because documentation of the survey methodology is often lacking. In Europe, the most inclusive and best-documented opinion survey is the Special Eurobarometer series on “Europeans and Modern Biotechnology”, first conducted since 1991 and then repeated in three-year intervals on behalf of the European Commission (Eurobarometers 35.1 in 1991, 39.1 in 1993, 46.1 in 1996, 52.1 in 1999, 58.0 in 2002, 64.3 in 2005 and 73.1 in 2010; see INRA Europe, 1991, 1993, 2000; European Commission, 1997; Gaskell, Allum & Stares, 2003; Gaskell, Allansdottir, Allum, et al., 2006, 2010).

Like all public opinion instruments, the Eurobarometer attempts to gauge the overall level of attitudes towards a group of issues in the general public. For a variety of reasons, the validity of such measurements can never be fully ascertained. Even minor changes in the wording of attitude items, the selection of response scale labels, or the order and thematic context of the questions can lead to relatively large changes in the level of reported attitudes towards the issue at hand. The Eurobarometer is no exception to this; however, it uses the same question and response format to measure attitudes towards a variety of different biotechnology applications, and it maintains a core of attitude items over time. Hence, comparisons of attitudes towards different applications and over time become possible. The cross-cultural validity of the instrument is still unknown. Therefore, statistics derived from aggregation over the different national sub-samples within the Eurobarometer survey should be interpreted with a certain degree of caution.

3.1 Trends Over Time

The Eurobarometer contains a section in which respondents are asked to state their optimism with regard to groups of technologies (“I am going to read out a list of areas in which new technologies are currently developing. For each of these areas, do you think it will improve our way of life in the next 20 years, it will have no effect, or it will make things worse?”). One of these is biotechnology, and it has been included in all Eurobarometers that were conducted. A comparison over time of the index “optimism about biotechnology” shows an interesting effect (Figure 1). In the beginning of the 1990s, the majority of EU citizens were optimistic about the future impact of biotechnology. In the mid-1990s, public opinion became gradually more sceptical until it reached bottom in 1999, reflecting the heated controversy before the announcement of the moratorium. In the years of the moratorium, public opinion gradually recovered. In 2005, after the lifting of the moratorium, EU citizens were as optimistic again about the future impact of biotechnology as they were in the early 1990s.

Since 2005, a divergence can be observed in the optimism index. In member states where the coexistence debate was characterised by high level of controversy (e.g., Austria and Germany) and ended in cultivation bans, optimism has fallen. In countries where the coexistence debate was more liberal (e.g., Spain) and where GM crops are still cultivated, optimism levels remain high

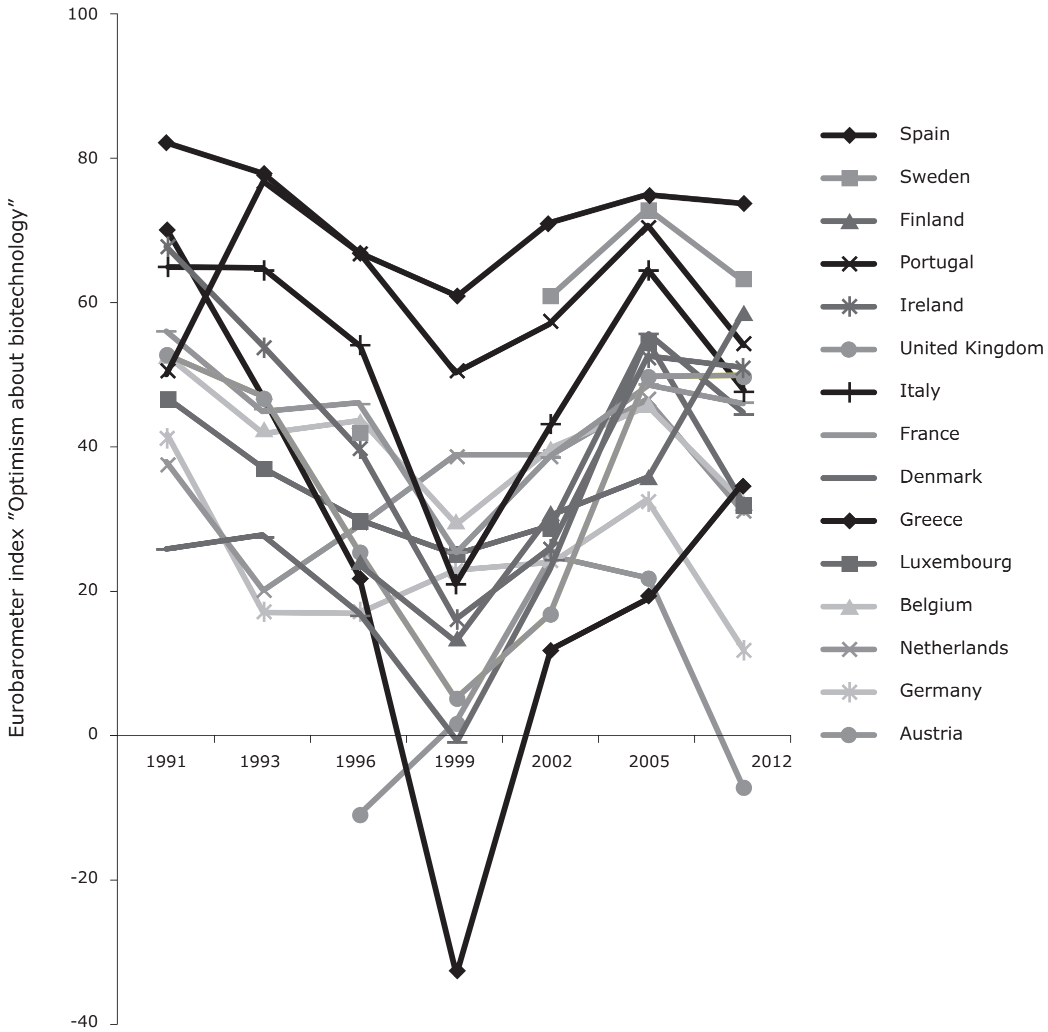

Figure 1: Trends over time in the Eurobarometer index "optimism about biotechnology" (Gaskell et al., 2010; EU-15 countries only).

Eurobarometer 64.3 (Gaskell et al., 2010) was the first of the Special Eurobarometer survey on modern biotechnology that was also conducted in Switzerland. Compared to the other countries participating in the survey, Swiss citizens reported medium levels of optimism about biotechnology and genetic engineering. The value of the optimism index was 32, similar to the value for Belgium, the Netherlands and Luxembourg.

3.2 Attitudes Towards Different Gene Technology Applications

The latest Eurobarometer (Eurobarometer 64.3; Gaskell et al., 2010) contained three example applications of gene technology in food and agriculture about which respondents were questioned in some detail ("Genetically modified food made from plants or micro-organisms that have been changed by altering their genes. For example, a plant might have its genes modified to make it resistant to a particular plant disease, to improve its food quality, or to help it grow faster" and "Some European researchers think there are new ways of controlling common diseases in apples – things like scab and mildew. There are two new ways of doing this. Both mean that the apples could be grown with limited use of pesticides, and so pesticide residues on the apples would be minimal. The first way is to artificially introduce a resistance gene from another species such as a bacterium or animal into an apple tree to make it resistant to mildew and scab. The second way is to artificially introduce a gene that exists naturally in wild/crab apples which provides resistance to mildew and scab"). Previous Eurobarometers had included two other example applications, including pest-resistant crops ("Taking genes from plant species and transferring them into crop plants to make them more resistant to insect pests") and processed foods with changed properties ("Using modern biotechnology in the production of foods, for example to give them a higher protein content, to be able to keep them longer, or to change the taste").

In all Eurobarometer surveys, consumers were asked to indicate their attitudes towards the example applications on four different dimensions, including perceived usefulness, risk, moral acceptability, and overall support, using a response scale ranging from 1 (totally disagree) over 2 (mostly disagree) and 3 (mostly agree) to 4 (totally agree). In the 2002 survey (Gaskell et al., 2003), pest-resistant crops scored slightly above, and processed foods with changed properties slightly below the neutral scale midpoint when evaluated for usefulness, moral acceptability, and overall support, whereas the scale midpoint. Both scored slightly above the midpoint when evaluated for risks. In the 2005 survey (Gaskell et al., 2006) the scores for GM food were similar to the ones obtained in 2002 for processed foods with changed properties. In the 2010 survey (Gaskell et al., 2010) the scores for the GM food example remained more or less unchanged compared to the previous survey. The examples of transgenic and cisgenic apples that had been introduced in the 2010 survey were evaluated much more positively by the Eurobarometer participants than GM foods in general. Furthermore, cisgenic apples were evaluated more positively than transgenic apples.

To the extent that the Eurobarometer results can be trusted, given the methodological limitations of opinion polls, EU citizens seem to have relatively neutral or weakly negative attitudes towards gene technology in food and agriculture, with slight variations upwards or downwards depending on the particular example application they are confronted with in a survey.

Swiss citizens participated 2010 for the first time in the Eurobarometer (Gaskell et al., 2010). 20% responded with "mostly agree" or "totally agree" to the question as to whether the GM food example (see above) should be encouraged, a level of support similar to that observed in neighbouring, relatively GM-sceptical EU member states such as Germany, Italy and Austria. The transgenic and cisgenic apple examples were supported by 23% and 44% of the Swiss participants, respectively – again, a level similar to that observed in Germany, Italy and Austria and thus among the more GM-sceptical countries participating in the Eurobarometer survey.

3.3 Effects of Demographic Characteristics

A consistent finding in all Eurobarometer surveys was that attitudes towards GM foods were dependent on two demographic background variables: gender and age. Younger Europeans tended to have more positive attitudes towards all types of GM foods than older Europeans, and men tended to have more positive attitudes than women. According to logistic regression results reported by Gaskell et al. (2003, p. 41), both effects were relatively strong: the odds that a respondent would state overall support for GM foods of the different types included in the survey increased between 22% and 25% as a function of age group (when respondents aged 15 to 39 were compared to respondents aged 40 and above), and between 18% and 29% as a function of gender (when male respondents were compared to female respondents). Formal education, on the other hand, did not have significant effects on the overall levels of respondents' attitudes, and neither did the dominant religious denomination of the respective EU member state respondents were residents of.

3.4 Knowledge About Biotechnology

Beginning with Eurobarometer 39.1 (INRA Europe, 1993) and ending with Eurobarometer 64.3 (Gaskell et al., 2006), the Eurobarometer surveys included a “knowledge quiz”, measuring objective knowledge about biotechnology and related natural science issues. The quiz includes items like, for example, “There are bacteria which live from waste water” and “Ordinary tomatoes do not contain genes while genetically modified tomatoes do not” which are answered on a correct-incorrect scale. In the absence of a gold standard, it is not possible to define what number of correct responses in this quiz would constitute little, medium, considerable, or detailed knowledge. On a global average, EU citizens seem to be able to answer a little more than half of the knowledge items correctly[2], with slight variations upwards and downwards de-pending on the member state they are citizens of. Citizens of northern EU member states tend to have above-average numbers of correct responses, whereas citizens of southern EU member states. Despite ongoing efforts to inform the general public about modern biotechnology, the average level of knowledge appears to remain relatively static across all EU member states.

3.5 Trust in Actors and Institutions

All Special Eurobarometers on Europeans and Modern Biotechnology included items that asked the respondents to indicate whether they trusted different actors and institutions involved in the development, commercialization, regulation, and public debate of biotechnology. The ranks of the different actors remained relatively static over time (high trust in medical doctors, consumer organisations, and university scientists, low trust in national governments, and the media), with the exception of environmental organisations and retailers, whose trustworthiness dropped sharply after 2002, and industry, whose trustworthiness increased after 2002. It is interesting to note that, in the period 1996 to 1999, all actors and institutions lost trust to a certain degree. The heated public debate of the years 1998 and 1999 may have been responsible for this: mutual allegations of scientific misconduct, vested interest, and deliberate distortion of facts during and after the Pusztai and Monarch-butterfly affairs may have harmed the reputation of all actors and institutions that were involved in the controversies at the time.

Survey results reported by Bonfadelli (2010; the survey was conducted as a part of NRP59) for Switzerland show a similar pattern as in the EU. Among the various stakeholder groups involved in the public debate on GM crops and foods, universities were were most trusted by Swiss citizens, followed by consumer organisations, environmental organisations, medical doctors, animal welfare groups, ethicists, agricultural lobbies, the federal council, and the large retailers. Only the media and the agro-chemical industry were distrusted by a majority of Swiss citizens. Interestingly, comparisons with previous surveys showed that universities have greatly increased their trustworthiness in the eyes of Swiss citizens. In 1997, 42% of the survey participants reported that they trusted universities. In 2002/2003, this figure had decreased to a mere 26%. By 2010, the image of universities had recovered so well that no less than 70% of the survey participants reported that they trusted universities.

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[2] Note that the items in the Eurobarometer knowledge quiz have a dichotomous true-false format. The expected value due to guessing alone would already be 50% correct.

4. Consumer Behaviour Towards Genetically Modified Products

All research reviewed up until now used methodologies that actively raised the issue of gene technology to the top of participants' minds. Such conditions are artificial, of course. As every newspaper editor, TV producer and advertising professional can certify, it is extremely difficult in real life to capture people's attention even for seconds. In a similar way, the mere fact that a food product carries a "genetically modified" label does not necessarily influence consumers' buying behaviour. Purchasing decisions in retail stores are typically made in a matter of seconds, depending on the category, the number of different product of the same category that are available in a store, consumers' familiarity with these products, the time pressure felt by consumers, and whether any of the available products are featured by sales promotions (for general reviews, see Cowburn & Stockley, 2005; Grunert & Wills, 2007). Hence, the amount of information that consumers process in a given choice episode is usually quite limited.

4.1 Attention to Information on Food Packages

The labelling regime in the European Union requires that genetically modified ingredients in foods are declared in the ingredients list, using a format like *"Ingredients: [...], soybeans (genetically modified), [...]"*. The ingredients list is usually displayed in very small print on the back or side of the package. Obviously, a labelled GM ingredient can only influence a consumer's choice when he or she reads the ingredients list. This, however, seems to be a rare event: attention-tracking experiments by Scholderer, Hagemann, Sørensen and Czienskowski (2007) suggest that a maximum of 5% of consumers are likely to read ingredients lists on food packages, and even this only in cases where the product is completely unfamiliar.

The largest field investigation of consumer attention to label information was conducted by Grunert and Wills (2009), sponsored by the European Food Information Council (EUFIC). Altogether 11,800 consumers from six EU member states were unobtrusively observed in retail stores. On average, consumers spent 25 seconds (in the UK) to 47 seconds (in Hungary) per category on handling the products and making their choices. Immediately after consumers had made their choices, they were approached by the observers and asked whether they had looked for any nutrition information on the package of the product they had chosen, and if so, which kind of information they had looked for. Averaged across the six countries in which the research had been conducted, 0.49% of consumer indicated that they had looked for a "genetically modified" label on the package.

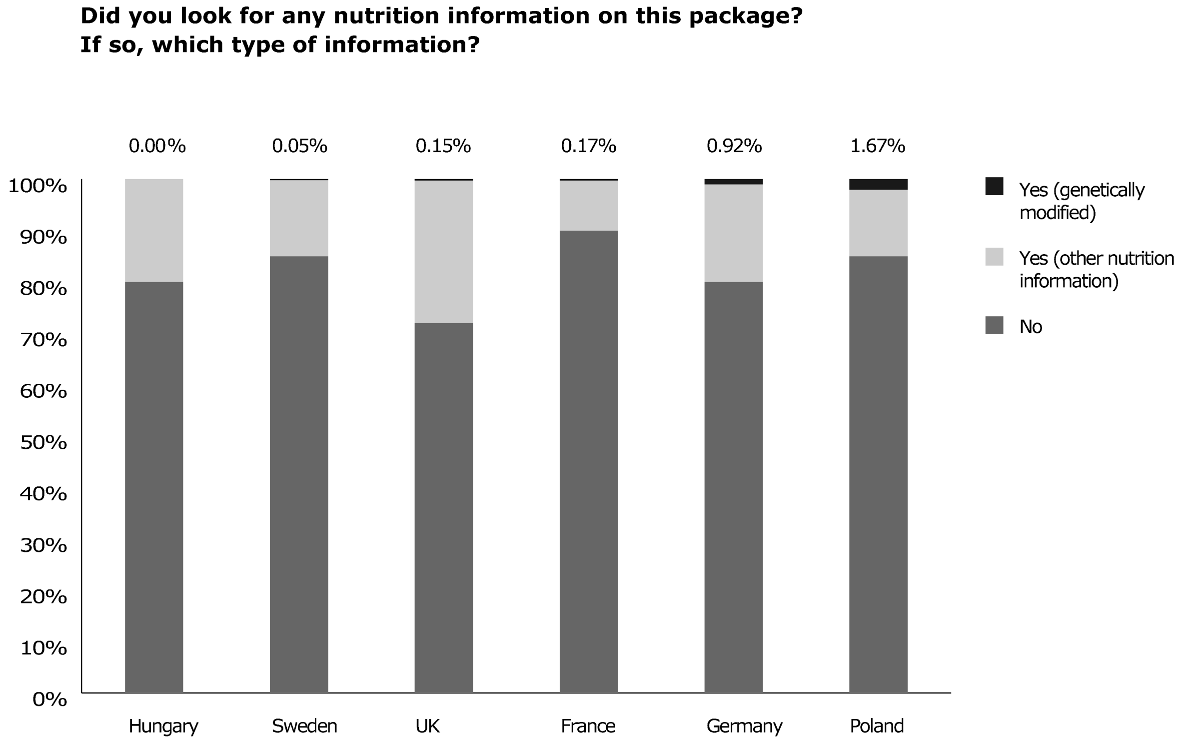

Figure 2: Results of in-store interviews (Grunert & Wills, 2009; the data were re-analysed for the purpose of the present report by Grunert, 2009, personal communication).

4.2 Influence of GM Labelling on Preference and Choice

Experimental choice studies reported by Noussair, Robin and Ruffieux (2002, 2004) and Scholderer and Frewer (2003) suggest that even an artificially magnified GM label has relatively little influence on consumers' choices between tangible products. Effects can usually only be observed when the issue is explicitly raised via additional communications in the choice situation. Although these results point to a negligible effect of GM labelling on consumers' choices, a substantial number of studies in the agricultural economics literature have attempted to measure some sort of "true" willingness to pay in isolation from the naturalistic context of consumer choice. The results of these studies shed a rather worrying light on the reliability and validity of typical willingness-to-pay experiments in general.

Lusk, Jamal, Kurlander, et al. (2005) report a meta-analysis of 25 primary studies that attempted to estimate the price premium which consumers are willing to pay (or accept) for a non-GM product relative to a GM product of the same category. The 25 primary studies yielded 56 useable effect sizes and one extreme outlier. After aggregation, the authors estimated the mean price premium consumers were willing to pay or accept for a non-GM product, relative to a GM product, as 29% (extreme outlier excluded). However, the effect size distribution was skewed (median: 19.5%), and there was a large variation between effect sizes (standard deviation: 46%). Figure 3 shows a histogram of the effect size distribution.

An updated meta-analysis was reported by Dannenberg (2009). Based on 114 effect sizes extracted from 51 primary studies, she estimated the mean price premium consumers are willing to pay for a non-GM product, relative to a GM product, as 45% (extreme outlier included). Again, the effect size distribution was highly skewed (median: 18%), and there was a very large variation between effect sizes (standard deviation: 92%). A moderator analysis indicated that the main sources of heterogeneity were the method by means of which the preferences had been elicited, the year and country in which the study had been conducted, and whether the GM products had been described as having direct consumer benefits or not.

It should be noted that all primary studies included in the Lusk et al. (2005) and Dannenberg (2009) meta-analyses had been based on stated preferences, elicited in laboratory experiments or by means of survey methods; none of them had been based on revealed preferences inferred from actual transaction data.

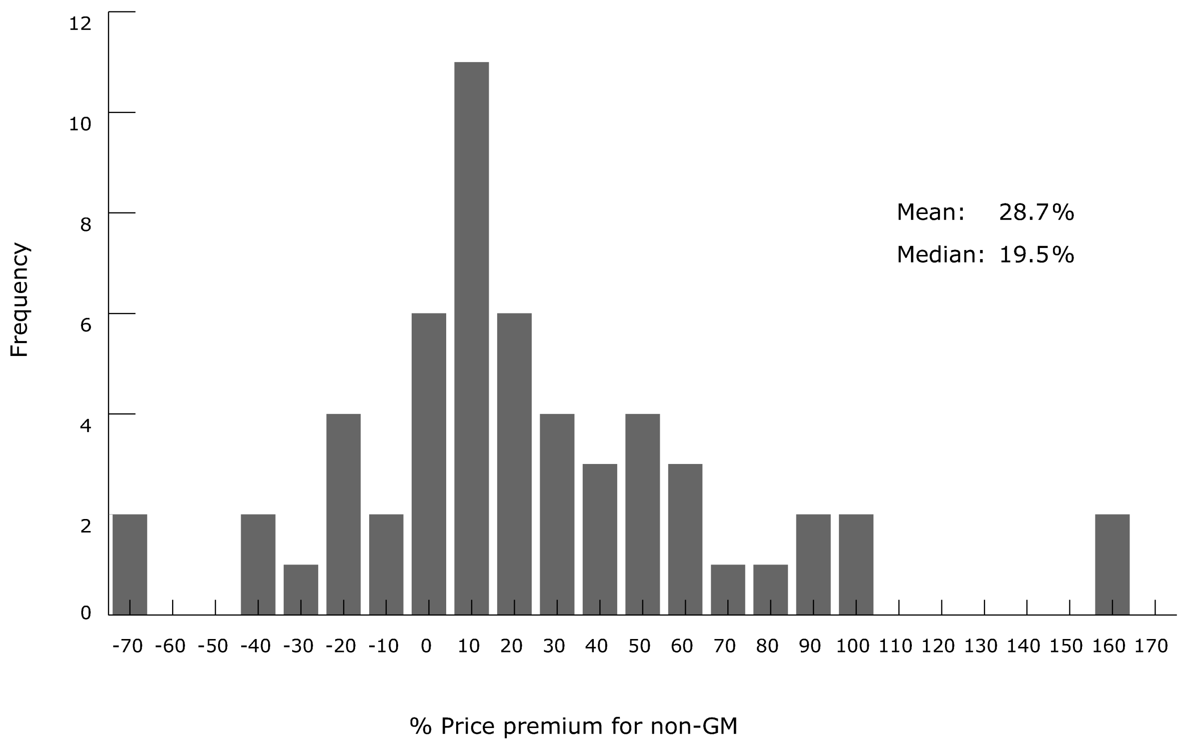

Figure 3: Histogram of the effect sizes included in the meta-analysis reported by Lusk et al. (2005). One extreme outlier was excluded.

Only five studies have been reported in the international literature until now that avoided this weakness. Mather, Knight and Holdsworth (2005) conducted a field experiment in New Zealand, selling different types of cherries at road stalls. One of the cherry varieties was labelled as a "spray-free," genetically modified Bt variety. Consumers showed stronger preferences for the GM cherries than for the conventional and organic cherries that were the alternatives, but were also more sensitive to changes in the price of the GM cherries. The observed volume share of the GM cherries was 27% in this study. The study was replicated by Knight, Mather, Holdsworth and Ermen (2007) in Belgium, France, Germany, Sweden, and the UK. Among European consumers, preferences for the "spray-free" GM cherries were slightly lower than among consumers from New Zealand: the observed volume shares of the GM cherries varied between 17% (in the UK) and 22% (in Germany)[3].

[3] The Mather et al. (2005) and Knight et al (2007) papers do not report sufficient statistics from which willingness to pay could be estimated.

Aerni, Scholderer and Ermen (2012; the study was conducted as part of NRP59) report a field experiment in which three types of corn bread were sold at market stalls in five different cities in the French and German-speaking parts of Switzerland. One type of corn bread had been produced from conventional maize, one from organic maize and one from genetically modified Bt-11 maize. All were clearly labelled. In addition, the size of the breads and their price were experimentally varied. The econometric analysis indicated that no more than 0.7% of the variation in consumer's choices could be explained by the attribute "genetically modified".

Marks, Kalaitzondonakes and Vicker (2004) conducted an almost ideal demand system analysis of the Dutch markets for canned soup, frozen processed meat, frozen pizza, and processed fish. Their analysis was based on weekly scanner data aggregated across Dutch supermarkets, collected (a) before and after the European Union's GM labelling regime entered into force in 1997 and (b) before and after the labels were removed in 2000 when sourcing of GM-free ingredients had been established by all suppliers. The change in labelling had no significant impact on the expenditure shares of GM and non-GM products. Lin, Tuan, Dai, Zhong, and Chen (2006) report a similar analysis of the Chinese market for vegetable oils, based on monthly scanner data which had been collected in retail stores in Nanjing before and after the Chinese GM labelling regime entered into force in July 2003. The expenditure shares of soybean and blended oils based on genetically modified varieties dropped by no more than 2% (from a baseline of over 80%), indicating that the introduction of compulsory labelling of GM ingredients had a weak effect on consumer demand. Taken together, the results of the studies that can be considered externally valid suggest a negligible impact of GM labels on the in-store purchasing behaviour of consumers.

5. Stakeholder Positions and Acceptance in Value Chains

5.1 Retailer Positions

Since the late 1990s, major retailers have excluded GM ingredients from their own-brand or private label products, as a measure to respect consumers' preferences in the EU (Devos et al., 2009). A qualitative survey of GM food labels in French supermarkets confirmed that there are almost no GM-labelled products on the shelves (Gruère, 2006), herewith confirming that EU food processors and retailers still favour non-GM products. Moreover, GM food products on retail shelves are targets for pressure groups opposed to genetic engineering (Carter & Gruère, 2003), and could therefore damage the retailers' corporate image. Finally, due to the possibility of GM admixtures, some food manufacturers are reluctant to purchase agricultural commodities from regions where GM crops are intensively grown (Smyth et al., 2002).

However, the Spanish Bt maize case shows that the labelling of products as containing GM material does not necessarily lower their market value. Spanish GM and non-GM maize are stored and processed together for sale as animal feed, and according to the labelling requirements the derived dairy and livestock products from animals fed on GM feed do not need to be labelled as GM.

5.2 Food Industry Position

Bagchi-Shen and Scully (2007) examine the characteristics of small and medium-sized enterprises involved in the agricultural biotechnology sector. Specific objectives of their study were to understand firm-specific strategies to remain competitive in an uncertain business environment and the examine the impact of government/policy and farmers on strategies. These authors state that the controversial nature of processes used and the ethical debate surrounding genetically modified organisms contribute to an ongoing struggle for these firms in negotiating their position in society as innovators. The data from this study suggest that firms are worried only about science; as the survey probes into firm-level evaluation of external actors, the importance of national and local-regional initiatives stands out. The study especially points towards significant gaps in the understanding of the relationship between firms (as innovators), users (farmers who are the traditional innovations, and the government (regulator-facilitator) in the the agro-bio subsector of the biotech industry. Last but not least, the authors point towards the need to engage other partners such as food companies, wholesalers, retailers and consumer groups in understanding the prospect of agro-bio.

Demont and Tollens (2004) indicated that by 2004, most sugar industries have not even adopted a strategy for the herbicide-tolerant sugar beet technology, but they remark very specifically, that the sugar industry in Switzerland does not want GM beet. Although the potential value of herbicide tolerant sugarbeet was found to be particularly high in the study presented by Demont et al. (2008a) (see further), the sugar industry's fear for losing domestic and export markets was mentioned as the major impediment for the introduction of GM beet. However, these authors are noted that the decision of one processor to allow GM beets in general may influence others, and could begin a chain reaction in the global sugar sector. Furthermore, Demont and Dillen (2008) reported that lack of sugar company acceptance has hampered the introduction of GM sugar beet in the USA until 2008, and suggest that owing to the observation that consumer concerns seem to have subsided, this technology has been introduced at a large scale in the USA in the year 2008.

5.3 Farmers' Attitudes Towards Agricultural Biotechnologies

Several studies have reported on farmer's attitudes towards agricultural biotechnologies. Nevertheless, Guehlstorf (2008) points to a notable omission in the political debate about biotechnology in the United States: the opinion of farmers who cultivate GM crops. The study indicates that, although national studies indicated that larger yields are the most common reason for GM adoption, qualitative information obtained through depth interviews with farmers suggests that the potential of GM crops to increase revenue per acre does not truly reflect all the concerns of modern farmers. For example, farmers who use GM seeds indicate that they constantly question the social impacts of their agricultural practices. Guehlstorf (2008) concludes that GM policies should be restructured as a political rationalisation of both economic modelling and political theory because this research suggests that farmers' business decisions are utility calculations that consider economics without ignoring environmental and political contexts. Famers' concerns about non-economic risks suggest that they need more information about GM crops and that governmental policies should respond to their interests, as they are more democratic or pluralistic than industry or consumer arguments.

Chong (2005) assessed empirically the perception of the risks and benefits of a transgenic food crop (transgenic Bt eggplant) by farmers in India. The findings of this study indicated that economics benefits, safety concerns, and accountability are most salient to Indian farmers' perception of the risks and benefits of Bt eggplant. None of the 100 farmers involved in the study mentioned moral concerns as an issue hampering their adoption of the technology. The findings also make clear that economic benefits outweigh perceived risks. This study concluded that economic are more salient than moral concerns to Indian farmers' perception of Bt eggplant. This study pertains explicitly to the situation in a developing country and recommends to focus on economic benefits, safety concerns and accountability as key variables explaining farmers' attitude (and possible future adoption) of agricultural biotechnologies.

Another study performed with farmers growing eggplant in India (Krishna & Qaim, 2007) analysed ex ante the adoption of Bt eggplant technology. The average willingness-to-pay (estimated through the contingent valuation method) was more than four times the current price of conventional hybrid seeds. The authors further noted that, since the private innovating firms has also shared its technology with the public sector, proprietary hybrids will likely get competition through public open-pollinated Bt varieties after a small time lag, farmers' willingness-to-pay for Bt hybrids might decrease 35%, herewith decreasing the scope for corporate pricing policies. Nonetheless, the study shows that ample private profit potential remains. Analysis of factors influencing farmers' adoption decisions further demonstrates that public Bt varieties will particularly improve technology access for resource-poor eggplant producers. The result suggests that public-private partnerships can be beneficial for all parties involved.

Kondoh and Jussaume (2006) investigated how farmers position themselves with respect to controversial agricultural technologies through an empirical analysis of Washington State farmers' willingness to try GM technology on their farms. The study herewith contributes to a better understanding of how farmers' expressed willingness to use biotechnologies contributes to better understand how their diverse thoughts about controversial agricultural biotechnologies are shaped not only by their own experiences but also by social context. The study analyses data from a farmer survey conducted on a random sample of farmers from across Washington Stage. The results show that the production practises farmers utilise and the market strategies they employ may be at least as useful as farmers socioeconomic characteristics in explaining what type of farmers appear to be more or less interested in potentially using this technology. The relationship between the level of formal education and willingness to use GMOS is not straightforward fro m the study results. The authors conclude that it may hide differences between farmers with respect to where and how they received their formal education as well the types of knowledge they gained. The study recommends recognising the diversity that exists in farmers interests vis-à-vis particular technologies and to explore how these interests are shaped by farmers past and present social networks and life experiences.

Hall (2008) points to the fact that current pro-GM and anti-GM positions are largely based on the positions adopted by the public, including consumers, non-governmental organisations, and industry and corporate bodies. One body largely lacking from this debate is farmers, and yet their decisions about whether or not to cultivate GM crops are crucial to the future of the technology in European agriculture. Hall investigated Scottish farmers' attitudes to GM crops. The result of this study revealed three discourses. First, one included to be positive towards the idea of GM and demonstrating an expectation of benefits. The second one representing a more uncertain position, wary of the potential risks of the technology but likely to be reluctant adopters. The third describing a group who demonstrate a somewhat fatalistic attitude towards the issue of agricultural biotechnology adoption and impact. The findings from this study suggest that farmers may be less profoundly pro- or anti-GM than other groups involved in the debate. This is significant of they represent the "middle ground" between the biotechnology industry and the public.

5.4 Role of Famers' Knowledge and First-Hand Experience

Kaup (2008) examined the influence of farmer knowledge upon decision making processes related to the adoption and cultivation of Bt corn using data gathered from farmers in Minnesota and Wisconsin. This author argues that farmers are 'reflexive' actors who actively negotiated between expert and local knowledge when deciding to plant Bt corn. Furthermore, the paper hypothesises that farmers are more likely to be influenced by their first-hand or local experiences than by state or expert observations.
Also Maruo and McLachlan (2008) report on the impact of farmers' knowledge in relation to agricultural biotechnologies' risk perceptions. They explore the role for Canadian farmers' knowledge and their decade-long experience with herbicide-tolerant canola in the risk analysis of GM crops. They conclude that the main benefits associated with HT canola were management oriented and included easier weed control, herbicide rotation, and better weed control, whereas the main risks were more diverse and included market harm, technology use agreements, and increased seed costs. Not surprisingly, benefits and risks were inversely related and the salient factor influencing risk was farmer experiences with HT canola volunteers, followed by small farm size and duration using HT canola. The study concludes that farmer knowledge is a reliable and rich source of information regarding the efficacy of HT Crops, demonstrating that individual experiences are important to risk perception.

While investigating and reporting on Spanish consumer attitudes towards GM food, Noomene and Gil (2007) mention: "...in spite of the general acceptance of GM technology among farmers, consumers have shown more concern." They suggest that a large majority of famers in Spain have positive attitudes towards the use of agricultural biotechnologies.

Heller (2007) reported on farmers' attitudes towards agricultural biotechnologies from an anthropologic perspective. The paper reports that scientists often define food quality in terms of technoscience, herewith assessing issues like food safety. On the contrary, small farmers often appeal to technes of production, herewith positioning GM as a rupture with artisanal culture. GMOs are designated as *la malbouffe*, or bad food, and as opposed to the idea of protection and preserving artisanal technes. While many cast GMOs as "unnatural", notions relating GMOs as "uncultural" even emerge. In this context, the French small farmers' union Confederation Paysanne posits culture against "culturelessness" associated with techno-science and industry-driven foods such as fast food and GM food.

Specifically with respect to coexistence in the EU, Bertheau (2009) concluded that farmers (interviewed as a stakeholder group in the Co-Extra stakeholder workshops) are inclined to view coexistence regulatory frameworks as yet another set of requirements that will increase the amount of paperwork they have to do. As a results, farmers were generally not in favour of having to be certified or licensed to be able to grow GM crops.

5.5 Acknowledging Heterogeneity Among Farmers

Impact assessments of monopolistically priced technologies, such as agricultural bio-technologies, are often based on cross-sectional comparisons of average cropping budgets while ignoring heterogeneity of farmers, i.e. the approaches fail to separate the segments of potential adopters and non-adopters. As such, these impact assessments underestimate the true impact of these technologies because of homogeneity bias. Numerous factors may explain differences in the pay-off of adopting GM technologies. These include the extent and nature of pest or insect exposure, the type of pest or insect control practices used (and related differences in pest or weed control expenditures), farmers' spraying habits, differences in agro-ecological conditions and local levels of disruption of ecosystems, field conditions, planting history, climatic conditions, current machinery, management expertise and local market conditions that condition the profitability of GM products relative to conventional products (Demont et al., 2008a). As an alternative to the average cropping budgets approach, Demont et al. (2008a) have presented an improved method by explicitly modelling farmer heterogeneity under imperfect information.

Their analysis has revealed that, in spite of the quasi monopolistic upstream sector, farmers could substantially gain from GM technologies. the total potential value of GM crops is estimated at 82 million euro for two new EU Member States, namely Hungary and Czech Republic. Of this value 73% accrues to farmers in those countries and 27% is to the benefit of gene developers and the seed industry. This distribution of benefits is in line with literature on global benefit sharing of first-generation GM technologies. This study considered the impact in two countries with a typical semi-extensive or extensive farming system, which is very different from the nature of agricultural production in the EU-15 where intensive farming is dominant. The study concludes by indicating that the banning of GM crops could be counterproductive for the future competitiveness of enlarged EU agriculture. Furthermore, the authors remark that to the private benefits calculated in their analysis, possible environmental benefits have to be added. They conclude with the recommendation that policy makers in this domain should consider the benefits foregone as a result of too stringent regulations on regulatory approval and coexistence of GM crops and weigh market, environment, health and regulatory policy factors when making ex ante decisions on the regulation of GM crops.

In a related study focusing on herbicide tolerant sugarbeet adoption in Hungary and Czech Republic alone, Demont and Dillen (2008) predict adoption potentials of 60-80% of GM sugar beet, with the total value of this agricultural biotechnology estimated at 252-262 euro/ha.

5.6 Agricultural Sociology Considerations

Other socio-economic consequences are that coexistence measures imposed by law and laboratory analyses for testing, analysing and identifying the content of GM material and non-GM material will inevitable entail additional costs in the supply chain in order to ensure compliance with the labelling and traceability requirements (Menrad and Reitmeier, 2008, in Devos et al., 2009). A specific sociological consequence is that farmers who want to adopt

GM technologies might have to negotiate with their neighbouring farmers and landowners in the same region, and seek mutual agreements about their cropping intentions.

5.7 Macro Environment Effects

The study by Kurzer and Cooper (2007) identifies two macro-environmental factors that shape differences in EU member states' hostility with regards to genetically modified crops and foods. The core of the presented analysis pertains to the impact of the presence or absence of alternative food production regimes and specific food traditions. Their study indicates that, if a vigorous eco-farming or regional food specialities sectors exists (the first variable in their analysis), environmental and consumer organisations can cement a strategic alliance with small farmers' organisations. The resulting green-green bloc generally manages to heighten public resistance to genetically modified crops and foods, and thereby to exert also a strong influence on national policy makers. The second variable is the biotech industry, which, if strong enough, can usually prevail against even a strong green-green bloc.

Seifert (2008) compared key actors and mobilisation strategies of the Austrian and French anti-biotechnology movements. He notes that while, regarding public opinion and government policy, both countries are among the EU's most avid biotechnology opponents, their national protest movements are characterised by some striking differences. In the Austrian case, professional environmental organisations are vocal in the public debate while groups of critical farmers work rather behind the scenes. In France, by contrast, peasant activists lead a radical protest movement that looms large to the present day. The comparison sheds light on the diversity of new social movements in general, and on the impact of rural actors and agricultural policies on anti-biotechnology movements more particular. This comparison highlights the significance of national agricultural policies in the context of EU multi-level governance and assesses two contrary national movements in the two countries considered.

5.8 Stakeholder Views as Analysed Within Co-Extra

Custers et al. (2009) report that in general, there is an overwhelming wish among stakeholders in the EU to have GM labelling thresholds for seeds regulated and a general conviction and concern about the costs that coexistence regimes will entail in practice. Stakeholders also expressed concerns about the practicalities of sampling and testing strategies. They also deem harmonisation necessary, in particular to prevent unfair competition to emerge between different EU countries. Most stakeholders were found not to be in favour of a hybrid regulatory model with rules both on the European and country level. Some nevertheless stressed the need for flexibility, especially on the practical level. The authors also noted that there are differences between countries, which seem to be fuelled mostly by differences in the country's specific policy context.

6. Costs and Benefits of Agricultural Biotechnology

6.1 The Decision Maker's Challenge

The release of a transgenic crop is expected to provide immediate and future benefits through positive effects on yields, product quality, production costs and/or other characteristics of the crops. On the other hand, an immediate release may also expose society to potential environmental or health risks (Demont et al., 2004). The problem that decision makers face is that if they decide to release the transgenic crop and discover later that the crop has a negative impact on the environment and/or health, further action is required. They may be able to prevent consumption and thus limit the impact on health, but they cannot retrieve the genetic information released into the environment. Hence, the decision maker has to weigh the expected benefits of an immediate release not only against the risks, but also against the consequences of the option of delaying the decision until a future time. These consequences pertain to benefits foregone for different stakeholders, as well as loosing in terms of competitiveness or competitive position. For example, maintaining a complete de facto ban on GM crops has been estimated to cost Hungarian farmers 43 million euro annually, the largest part borne by farmers who are denied from using technologies that could help them confirm their competitive position in the EU (Demont et al., 2007).

As most of the GM technologies have been developed by the private sector and are protected by intellectual property rights which confer monopoly rights to the discoverer (which results in prices that are higher than they would be in a perfectly competitive market), policy makers are interested in benefit sharing of these technologies among involved stakeholders, both upstream (gene developers and seed companies) and downstream (domestic and foreign farmers, industries and consumers) in the supply chain (Demont et al., 2008a). A meta-analysis of ex post impact assessments of the benefits and costs of GM crops, most of which were performed in the USA, revealed that on average two thirds of the benefits of first-generation GM crops are shared downstream (mainly by farmers) whereas only one third upstream by gene developers and seed companies (Demont et al., 2007). In contrast to studies available from the USA, only very little is known about the potential impact of GM crops in terms of benefits and costs in the EU. Furthermore, an ex ante cost-benefit assessment is relevant and desirable from a societal point of view, since decisions to ban GM crops should at least consider the benefits foregone for farmers, and eventually also consumers (Demont et al., 2008a).

6.2 Value of Agricultural Biotechnology and its Benefit Sharing

Ex post welfare studies considering the case of the USA have indicated the distribution of benefits from agricultural biotechnology. Owing to the 1998 de facto moratorium on agricultural biotechnology in the EU, studying the potential welfare effects associated with agricultural biotechnology had to be done through an ex ante approach, which reveals the benefits forgone owing to the non-adoption of the technology, or the costs of the de factor moratorium (Demont & Tollens, 2004). The EUWAB-project (European Union Welfare effects of Agricultural Biotechnology; http://www.agr.kuleuven.ac.be/aee/clo/euwab.htm) has tried to estimate the impact of biotechnology innovations in the EU and its distribution among member countries, producers, consumers and input suppliers.

Demont et al. (2007) report that banning GM crops denies farmers access to potentially cost-reducing technologies in an increasingly competitive environment. They further present a review of global benefit sharing of GM crops literature. The global annual value generated by the worldwide adoption of a GM crop can be as large as 1.2 billion US dollar in the case of herbicide tolerant soybean. Per hectare values of individual GM technologies range from 25 US dollar to about 400 US dollar/ha. On average, two thirds of the global benefits are shared among domestic and foreign farmers and consumers, while only one third is extracted by the input supplying gene developers and seed companies in the form of gross technology returns. This benefit sharing seems to the general rule of thumb for first generation GM crops in industrial as well as in developing countries.

The same benefit-sharing rule of thumb applies to the EU. Results from benefit-sharing studies in the EU are also reviewed by Demont et al. (2007). Their compiled data are mostly the result of ex ante impact assessments, except in the case of Bt maize in Spain and the Czech Republic. Per hectare values for maize and oilseed rape range from 30 euro to 78 euro/ha, while the highest potential for value creation is recorded for herbicide tolerant sugar beet with a value of 242-335 euro/ha. The finding that the downstream (rather than the upstream) sector is the major beneficiary of biotechnology innovations is explained by the fact that farmers are heterogeneous with regard to pest pressure and weed infestation on their fields, and by the competition from the chemical (crop protection) sector. In order to provide economic adoption incentives for a critical mass of potential adopters, multinational gene developers and seed companies must lower their technology prices and engage in price competition with the chemical sector. The 2:1 benefit sharing is a direct reflection of the degree of heterogeneity among farmers' valuation of the first generation of GM technologies in arable farming around the world (Demont et al., 2007).

In the EU, only a limited number of member states have been commercially growing GM crops so far and only a few ex-post impact assessments have been published. These include the impact assessment on Bt maize in Spain by Demont and Tollens (2004) and Gomez-Barbero et al. (2008) and in the Czech Republic (Demont et al., 2008a), and herbicide tolerant soybeans in Romania (Brookes, 2005).

6.3 Value for the Case of Bt Maize in Spain

Maize is the world's most ubiquitous cereal (Demont & Tollens, 2004). Maize production is facing the European Corn Borer and Mediterranean Corn Borer as two economically important pests. Both insects cause physical damage to the plants and have caused severe losses in (Spanish) maize production. Crops can be protected through the use of insecticides or the spraying of sprays incorporating Bacillus thuringiensis (Bt), which is a naturally occurring soil borne bacterium that produces crystal-like proteins that selectively kills insects. Alternatively, Bt maize or maize in which a gene of the bacterium has been inserted, causing the maize to produce the toxin, can be grown.

According to James (2003), yield gains due to the growing of Bt maize were estimated at 5%in temperate areas and 10% in tropical areas. Farmers were reported to assign Bt maize a high value because it is a convenient and cost effective technology that allows them to manage risk in a uncertain environment and offers insurance against major crop losses in periods when pest infestations are exceptionally high. The technology also offers safer feed and food products than conventional maize with lower levels of harmful mycotoxins.

In 1998, two transgenic maize varieties from Syngenta Seeds were approved for commercialisation in Spain. Following the 1999 EU de facto moratorium on new approvals of transgenic crops, Syngenta voluntarily agreed to limit its transgenic seed supply to the 1998 level for the variety Compa CB until the moratorium is lifted (Brookes, 2002). This constraint was lifted in 2003. As a result, by 2004 Spain was still the only EU country were transgenic crops were grown by farmers.

Demont and Tollens (2004) estimated the first impact of this biotechnology innovation in Spanish agriculture using a bio-economic modelling approach.Results from their analysis are an aggregated producer surplus during 1998-2003 of 10.3 million euro and an aggregated seed industry profit of 5.2 million euro during the same period. This means farmers gained two thirds (64.5%) of the total benefits, while the seed industry gained one third (35.5%). This benefit sharing was consistent with other studies, notably American literature that also shows that farmers are the main beneficiaries of agricultural biotechnology innovations. In the long run, these benefits flow from farmers to downstream sectors, retailers and finally to consumers.

Uncertainty analysis revealed that the idea of agriculture losing money on average by adopting Bt maize is very unlikely as this scenario occurred only in 0.006% of the model iterations. The welfare distribution between farmers and industry is mainly shaped by three factors: (1) the theoretical (assumed) loss that can be caused by corn borers, (2) the cost of the conventional technology (insecticide prices and efficacy), and (3) the license between the biotechnology industry and the farmer. Since the domestic maize demand was modelled as infinitely elastic in a small open economy, no price decline was generated by the model and therefore no benefits accrued directly to Spanish consumers. Demont & Tollens (2004) note that the Spanish maize production is highly elastic, meaning that if the Spanish maize sector faced a less elastic downward sloping domestic demand, a technology-induced supply shift would quickly erode domestic prices. Owing to the EU policy with minimum price guarantees for maize, Spanish farmers are largely protected against price declines and the major shift would be a sharp production boost. This, in turn, would increase the self-sufficiency of Spanish maize production, and since most of the Spanish maize supply is used by the animal feed industry, it would yield short term benefits to the animal feed industry, cattle farmers, processors and retailers, and in the long run to consumers through lower animal product prices.

The ex post welfare calculation presented by Demont and Tollens (2004) only contains private reversible effects. In reality, technologies also engender non-private or social effect, also called externalities. With respect to Bt maize, the major negative non-private effects include (1) effects on non-target organisms, (2) gene flow, (3) the impact of the Cry1Ab proteins in soil and surface water, (4) the evolution of pest resistance, (5) the development of antibiotic resistance, (6) food and feed safety aspects of Bt maize. Positive non-private effects include (1) lower contamination of aquifers with insecticides, (2) lower farmers' exposure to insecticides and better farmer health, and (3) lower levels of mycotoxin fumonisin in Bt maize and derived products (James, 2003, in Demont & Tollens, 2004).

6.4 Potential Value of Herbicide-Tolerant (HT) Sugar Beet

An important characteristic of any economic impact assessment reported in literature is that it builds heavily on assumptions and caveats related to the agricultural policies in the considered study areas. For example, when considering the case of herbicide-tolerant sugar beet production in the EU, the Common Market Organisation is a crucial factor. Furthermore, for this particular crop which is one of the most heavily protected agricultural commodities, any market intervention might distort the flow of benefits from adopting a particular technology, e.g. biotechnology in this case (Demont & Tollens, 2004). Demont and Tollens (2004) have developed a three-region model (EU, Rest of the World beet, Rest of the World cane) to capture the essence of sugar production and trade. Their analysis reveals that 53% of the benefits (global welfare effects estimated around 1 billion euro after 5 years of adoption) is accruing to the Rest of the World if they assume that beet producers in these countries (1) are able to achieve the same efficiency-enhancing effects through the use of the new technology, and (2) are not able to export the technology-induced surplus on the world market and further significantly erode the world market prices for sugar. Total producers' welfare increase is estimated at 949 million euro, shared 36% for the EU and 64% for the Rest of the World. The EU sugar beet industry captures the next largest share of the benefits (30%). Since minimum beef prices are fixed under the Common Market Organisation, no important price declines are possible. Therefore, the benefits essentially flow to farmers without affecting the processors. The third and smallest share of the benefits (17%) accrues to seed suppliers and gene developers. This limited ability of the input industry to capture a substantial part of the benefits is attributed to the fact that in a quota system, producers irresponsive to the world prices will decrease their land supply to the sugar industry rather than increase it. This negatively affects demand for the new technology and limits the profitability of input suppliers. Last but not least, EU consumers do not benefit from the innovation owing to the fact that EU intervention prices are exogenously fixed each year, and therefore no domestic price declines are engendered by the introduction of the technology (Demont & Tollens, 2004).

The possible impact of a major policy reform has been illustrated by Dillen et al. (2008). In July 2006, a new EU Common Market Organisation for sugar was introduced. The key feature of the reform were a progressive cut of the EU institutional price for sugar, direct compensatory payments for a part of the estimated revenue loss of farmers, and a single quota arrangement for the period 2006/07-2014/15. In order to facilitate the desired reduction in production, a buy-out scheme was installed allowing less competitive producers to reduce or abandon production. The study by Dillen et al. (2008) demonstrates that this radical reform of the EU sugar regime has greatly affected the sector, including an altering of the possible stream of benefits from an innovative technology such as the growing of transgenic herbicide tolerant sugar beet. The result show that farmers in uncompetitive member states have weaker incentives to adopt the new technology whereas former so-called B-sugar producers (medium-competitive producers) capture higher gains under the new regime because the new institutional price of B-sugar is slightly higher than the old institutional price. The new regimes further erodes incentives for uncompetitive producers and stimulates the exit of this group. The authors also note that the decrease in production costs in the European sugar industry following the adoption of the new sugar regime and the introduction of GM technology could potentially open the door to cost-effective bio-ethanol production, as the attitude of consumers to biotechnology in this area may well be sympathetic.

The 2009 study by Dillen et al. (2009) presents a farm-level analysis, expanded to a partial equilibrium model of the world sugar trade, and shows that even under the given condition of private market power, significant gains from the adoption of herbicide tolerant sugar beet accrue to farmers and consumers. The global value of herbicide tolerant sugar beet for society is estimated at 15.4 billion euro for the period 1996-2014, of which 29% is captured by farmers in the EU, 31% by farmers and consumers in the rest of the world, and 39% by the seed sector. However, the global sugar sector is foregoing most of this value as the technology is currently only accepted by the US sugar industry.

In the case of herbicide tolerant sugar beet, considering the rules set by the EU Common Market Organisation for sugar, a significantly negative effect of a yield increase on the seed sector's profits is expected. In highly protected sectors, such as quota systems, yield-enhancing technologies negatively affect their own demand, as farmers who are non-responsive to world prices will decrease their land allocated to the crop, lowering the derived demand for enhanced seed (Dillen et al., 2009).

6.5 Profitability of GM Plants in Switzerland

Within the Co-Extra project, Wolf and Vögele (2009) presented initial results from a profitability analysis of GM plants in Switzerland. Specifically, they evaluated time requirements, efforts and costs for Swiss farmers taking into account varying degrees of regulatory restrictions and technical feasibility. Their initial conclusion is that the cultivation of Bt corn becomes economically viable compared to the cultivation of non-GM maize once there is a light-to-moderate (10-25%) corn-borer infestation, provided that the seed premium does not exceed 25%. For small Swiss farmers with less than 25 ha arable land, the cultivation of Bt corn is only profitable if the corn-borer infestation is strong.

7. Coexistence: EU Experience and Agro-Economic Impact

7.1 EU Policy Background: Tolerance Threshold and Labelling

The regulations on the coexistence of GM and non-GM crops in Europe have been mentioned as "another challenge – apart from the maintenance of a state of quasi-moratorium – that threatens to paralyse the cultivation of GM crops in Europe" (Devos et al., 2008). The adopted EU coexistence policy aims to ensure that different cropping systems (conventional, organic or GM crop production) can develop side by side without excluding any agricultural option. The preservation of consumers' freedom of choice is the driving force behind the European Union (EU) coexistence policy. The EU coexistence policy with mandatory labelling and traceability of genetically modified (GM) products has been adopted because the maintenance of different agricultural production systems, including conventional, organic and GM farming systems, is a prerequisite for providing a high degree of consumers' and producers' choice (Devos et al., 2009). The coexistence of genetically modified organism (GMOs) with conventional and organic agricultural production is directly related to the practical choice of consumers and agricultural producers to respect individual preferences and economic opportunities, respectively (CEC, 2009). According to the Commission Recommendation of 23 July 2003, coexistence refers to the ability of 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 (Czarnak-Klos et al., 2010). Since coexistence only applies to approved GM crops, safety issues fall outside the remit of coexistence in the EU.

Because of the heterogeneity in farm structures, crop patterns and legal environments among EU Member States, the European Commission follows the subsidiarity principle for the implementation of legal coexistence frames (Devos et al., 2008). According to this principle, coexistence should be handled by the lowest authority possible. EU Member States may take appropriate national measures on coexistence in order to avoid the unintended presence of GMOs in other products (CEC, 2009), although it has been recognised that a certain extent of adventitious mixture may be unavoidable owing to the open system nature of agriculture. Within the EU, the development of specific legislation or non-binding coexistence guidelines is in the competence of individual Member States. As a result, different national and/or regional coexistence regulations have been established. In specific, 15 Member States adopted dedicated legislation on coexistence by 2009 and three further Member States notified drafts of the legislation to the Commission (EC, 2009).

To ensure coexistence between cropping systems, current legislation combines ex ante coexistence regulations and ex post liability schemes. Ex ante coexistence regulations consist of preventive on-farm measures to warrant that non-GM agricultural products comply with the legal tolerance threshold for the unintentional or technically unavoidable presence of approved GM material in non-GM products. Ex post liability schemes cover questions of liability and the duty to redress the incurred economic harm once adventitious mixing has occurred (Devos et al., 2008). Potential sources of admixing as identified in the case of maize, for example, are seed impurities, mixing in machinery during sowing, cross-fertilisation with GM, mixing in machinery during harvesting or mixing during transport, drying and storage (Czarnak-Klos et al., 2010).

The legal tolerance threshold applied in the EU is 0.9% for adventitious or technically unavoidable traces of GMOs in food, feed and organic products, while there is no official threshold in place for seeds. According to European legislation, GMOs as well as food and feed containing, consisting of or produced from GMOs have to be labelled accordingly in order to guarantee an informed choice at retail and consumer level. A direct implication is that products requiring such labelling have to be segregated from non-labelled products. If the content of GM material in a non-GM agricultural product exceeds the tolerance threshold, the product has to be labelled as containing GM material. Products which require labelling according to the Community legislation due to the admixture of GMOs can no longer be marketed with an organic label.

A new Commission Recommendation has been adopted on 13 July 2010, which provides Member States more flexibility to take into account their regional and national specificities and particular local needs of conventional, organic and other types of crops and products. Importantly, this new recommendation allows for Member States to decide to aim at lower levels of admixture, i.e. levels below the 0.9% threshold in cases where the presence of traces of GMOs are deemed to cause economic damage to operators who would wish to market products as not-containing GMOs (Czarnak-Klos et al., 2010).

7.2 Economic Incentives for Coexistence

Devos et al. (2009) have provide a comprehensive review of coexistence of genetically modified (GM) and non-GM crops in the European Union. EU member states are currently imposing or proposing isolation distances between neighbouring fields between 15m and 800m to keep GM-inputs due to cross-fertilisation (pollen flow) below the tolerance threshold. Spatial isolation has been reported as an efficient measure to reduce the extent of cross-fertilisation.

However, according to Devos et al. (2008), imposing wide and fixed isolation distances around GM maize fields entails four challenges to policy makers: (1) defining appropriateness of isolation distances, (2) feasibility of isolation distances without jeopardising farmers' freedom of choice, (3) accounting for regional heterogeneity of farming, and (4) proportionality to economic incentives. In many cases, isolation distances of 50 m were proven to be sufficient to comply with the tolerance threshold. Especially in areas where maize is grown on a substantial part of the agricultural area and/or where maize fields or small and scattered throughout the cropped area, large isolation perimeters might interfere with adjacent non-GM fields. Hence, if farmers do not concur with the respective cropping intentions of their neighbours, wide isolation distances might affect farmers' choice (possibilities) and freedom of choice, which contradicts European coexistence objectives. Furthermore, several factors that influence cross-fertilisation, such as cropping patterns, sowing or flowering dates, landscape, other crops, or physical and natural barriers, are heterogeneous, thus requiring flexible rather than fixed isolation distances. Last but not least, coexistence is only relevant when there are economic incentives for farmers to supply both GM and non-GM maize. Economic incentives of coexistence can easily be summarised as the adoption of Bt maize to capture so-called GM gains (mainly productivity and efficacy increases, and production cost reductions), or the cultivation of GM-free crops to capture GM-free gains (income generated through price premiums for non-GM crops) (Demont & Devos, 2008; See in this paper Box 1 "Economic incentives for coexistence").

Devos et al. (2008) further spell out the conditions under which economic incentives might manifest themselves in the market. Specifically, farmers who cultivate non-GM maize would only have an incentive to preserve the non-GM status of their production by applying coexistence measures if consumer have (1) strong and sustainable preferences for non-GM maize, and (2) are willing to pay significant price premiums for it. In markets where consumers are unwilling to pay premium prices for GM-free products, there is no coexistence issue stricto sensu. Only if the demand for non-GM crops is substantial, will they be sold on the market at a higher price than GM crops and will gains from specialisation in non-GM crops be realised (Demont et al., 2009).

7.3 Fixed Isolation Distances Versus Building in Flexibility

Devos et al. (2008) conclude that wide and fixed isolation distances, as currently proposed by many EU member states, fail to satisfy the challenges facing coexistence of different agricultural systems. As a result, the currently adopted EU coexistence policy is placing another barrier on the adoption of GM rather than contributing to the lifting of the EU moratorium.

Potential solutions lie in building in flexibility into ex ante coexistence regulations. Demont et al. (2009) propose three alternatives. First, allowing farmers to discuss who implements coexistence measures, i.e. building in ex ante regulatory flexibility which could allow farmers who adopt GM crops to contract out the implementation of coexistence measures to their non-GM neighbours in return for a compensatory payment in case the latter option is cheaper. Second, allowing farmers to negotiate the implementation of alternative coexistence measures, for example pollen barriers instead of isolation distances. Third, designing coexistence measures that are specific to farm structures, farming systems, cropping patterns and natural conditions in a particular region. The authors note that the latter case-by-case-based approach with plural advisory coexistence measures that are negotiable between farmers on a case-by-case basis and adaptable to different regional and local situations, will demand much administrative efforts.

The interaction between economic incentives and costs of coexistence has hardly been studied. A notable exception are the studies by Demont et al. (2008b) and Demont & Devos (2008), which was performed within the EU SIGMEA project (Sustainable Introduction of Genetically Modified organisms into European Agriculture). This study polarised two alternative ways of regulating spatial coexistence, namely the application of rigid minimum distance rules imposed on GM crop production, versus flexible segregation measures such as buffer zones that leave more freedom of negotiation between neighbouring farmers. Through analysing the farm-level coexistence costs, the findings of the study show that rigid coexistence rules such as large distance requirements may impose a severe burden on GM crop production in Europe. Such rules are furthermore found to be not proportional to the farmers' basic economic incentives for coexistence and hence not consistent with the objectives of the European Commission. In contrast, flexible measures are found to be proportional to the economic incentives of coexistence and less counterproductive for European agriculture. Average costs of flexible coexistence measures are estimated at about 2 euro/ha, which is significantly lower than the estimated cost of rigid coexistence regulations, which are about tenfold.

Interestingly, Demont et al. (2008b) identify a so-called domino-effect of successive GM area restrictions and related distance conflicts, which gradually raises coexistence costs and constrains adoption rates in the case of rigid coexistence regulations. This domino-effect is referred to as a theoretical spillover effect of farmer decisions in a GM-free crops-favourable market (Demont & Devos, 2008; see in this paper Box 3 "Domino effect").

Demont et al. (2008b) conclude that flexible measures would be preferable. These measures should be negotiable among GM and non-GM farmers because both have economic incentives to ensure coexistence in the long run.

Alternatively, GM and non-GM farmers could try to coordinate their crop allocations in time and in space and would take decisions that minimise transaction costs in the long run. Action such as clustering of activities, as described by Furtan et al. (2007), would tend to reduce overall coexistence costs (Demont et al., 2008). The study by Furtan et al. (2007) examined the feasibility of GM and non-GM technologies coexisting in a common physical landscape using the theory of clubs. Their conclusion is that a club can be created in which GM and organic agricultural production technologies can economically coexist in the same physical landscape. In their study, coexistence was found to result in an increase of economic welfare over a situation where only GM technology is used, but coexistence was found not to be Pareto superior (the situation where at least one party is better off while no party is worse off) because producers in the buffer zones would incur injury. However, organic producers were found able to compensate producers in the buffer zone while still being better off.

7.4 Cost of Coexistence in Supply Chains

As part of the Co-Extra project, Menrad and Gabriel (2009) concluded that significant additional costs are expected by organising coexistence between GM and non-GM products in the value chain and by maintaining mandatory (or voluntary) thresholds and regulations. Depending on factors like crop requirements, farming systems and situations, storage and elevating systems, processing strategies, monitoring management, among others, the total additional costs of co-existence and product segregation systems can raise up to 13% of the total product turnover at the gates of rapeseed oil mills or starch industries processing wheat and maize. Since the question of coexistence is currently only a hypothetical one in the EU, it is also expected that the implementation and permanent running of coexistence and segregation systems in the food industry can decrease a part of these additional costs due to savings and possible economy of scale effects.

It should be noted that the generated cost calculation model was applied on the food and feed value chains of wheat, sugar, rapeseed oil, soy and maize in several countries, including Switzerland. The authors remark that for a Swiss mill company the commodity delivering systems is quite manageable and the input testing of elevated rapeseed is negligible, which puts then in a more favourable (lower cost) situation as compared to bigger companies with several processing sites in other EU countries. Overall, a major determinant of the level of coexistence costs relates to the possibilities of the companies to apply certain segregation strategies in a cost-efficient manner.

Specific data on the costs of traceability and coexistence systems have been provided by Menrad et al. (2009) for Germany and Denmark. The price premiums reported for GMO-free rapeseed oil, sugar, wheat starch and wheat flour are mostly in the range of 2% to 10% on the final end products.

Additionally, Bertheau (2009) indicates that interaction with companies has been quite difficult and retrieval of quantitative data concerning economic issues related to coexistence has been almost impossible, either owing to a lack of internal awareness and analysis of the impacts, or owing to unwillingness to disclose any results competitiveness reasons of competitiveness.

7.5 Importance of Market Signals

Last but not least, Demont & Devos (2008) emphasise that the existence of a sustainable demand for GM-free crops is a precondition to justify extremely rigid and costly coexistence measures. Only if consumers have a strong and sustainable preference for non-GM crops, and are willing to pay significant price premiums for these products, will some farmers have an incentive to supply GM-free crops. If the opposite holds, strictly speaking, there is no coexistence issue and coexistence costs will purely reflect the costs of compliance to the established coexistence laws instead of the economic incentives for coexistence.

GM gains are naturally heterogeneous, since farmers operate under heterogeneous conditions with respect to land quality, pest pressure, managerial expertise, education and market access. In contrast, GM-free gains are homogeneous, since they apply to all farmers because they are generated by the interaction of aggregate demand and supply on the market for non-GM crops. Typically, as long as consumers are willing to pay significant GM-free price premiums, highly productive areas in which the incentive for growing GM crops is higher than the incentive for growing non-GM crops, will cluster as GM regions. In contrast, low productive areas can be expected to rapidly cluster into GM-free zones in an attempt to capture the GM-free gains. Ultimately, market signals stemming from consumer demand for GM-free products will shape the trade off between planting GM crops and supplying GM-free crops.

This analysis does not mean that, under weak market signals for GM-free crops, the entire landscape will be planted with GM crops. Adoption is usually incomplete for several reasons. These stem from farmers' uncertainty or risk aversion, as well as from the fact that GM seed prices will be higher in a market with monopolistic competition (which is the case) than under perfect competition. Therefore some farmers will find it profitable to adopt the technology, while others will not (Demont & Devos, 2008).

Last but not least, Binimelis (2008) points to the fact that considering economics incentives alone provides only a fraction of a more complex picture. This study presents qualitative research on the conceptualisation and implementation of the coexistence framework in two regions of Spain where about half of maize was GM in 2006. In this study, the concept of coexistence and its proposed implementation both fail to resolve previous conflicts and actually work to generate new ones through the individualisation of choice and impacts. Considerations of the social conditions in which the technology and the management measures are implemented were not taken in the implementation of coexistence. This resulted in the promotion of biotechnological agriculture over other alternatives.

7.6 Coexistence in Practice in the EU

The 2009 report from the Commission to the Council and the European Parliament on the coexistence of genetically modified crops with conventional and organic farming provides an overview of coexistence in practice in the EU (CEC, 2009). The report stipulates that:

- Liability in the event of economic damage to non-GM crops resulting from GMO admixture is a matter of civil law, which is the responsibility of Member States. All national jurisdictions provide a minimum of protection in case of such damage under the regular conditions of tort law. Some Member States have introduced specific liability regimes that apply specifically to damage resulting from GMO admixture. Almost all legal systems have specific rules on neighbours' disputes, which may also apply in the event of economic damage resulting from GMO admixture. Insurance products covering risks of GMO admixture seem not to be available on EU markets. In four Member States, however, insurance cover or alternative types of financial guarantee for potential economic damage are legally required or may be required following case-by-case assessment. Some Member States have established compensation funds (financed by a levy on GM crop production) for economic damage resulting from GMO admixture. No compensation has been paid from any of these funds so far. No instance of economic damage resulting from cross national border admixture of GMOs has been reported by the Member States.

- Fifteen Member States have adopted specific legislation on coexistence and draft legislation of three further Member States has been notified to the Commission. In some Member States, the development of a regulatory framework is not envisaged in the near future as the cultivation of GM crops on their territory has been deemed unlikely to take place. In some Member States, competence for coexistence lies at the regional level. No Member State indicated that the coexistence rules in place would be insufficient to ensure appropriate levels of segregation of GM and non-GM crops.

- In the majority of the Member States, GM crop growers have to inform their immediate neighbours, operators with whom they share agricultural machinery, the owners of property on which cultivation is intended, and (in three Member States) bee keepers within a certain perimeter around a GM crop field. The public is generally informed about the cultivation of GM crops via a public register. Some Member States require GM crop growers to undergo mandatory training or to demonstrate sufficient knowledge in order to implement the required segregation measures. Some also require obligatory consultation of neighbours, and in some cases also written agreement, specifically in relation to the implementation of isolation distances.

- The majority of the Member States have designed coexistence measures to prevent admixture levels exceeding the 0.9% threshold, whereas some indicated they strove for GMO admixture levels to be as low as possible. Isolation distances for maize production range between 25 m and 600 m with respect to conventional maize and between 50 m and 800 m for organic maize depending on the required cross-pollination levels. Since cross-pollination is only one possible source of admixture, isolation distances to reduce cross-pollination are usually set at levels to reduce admixture below 0.5% GM (often even around 0.1%) in the final crop to allow for other potential sources of contamination. Setting isolation distances to achieve the threshold of 0.9% would leave no margin for error or other sources of contamination. One Member State requires GM crop growers to observe isolation distances with regard to sites of established bee keepers.

- Many Member States require specific procedures, or prohibit the cultivation of GM crops in areas under environmental protection. Regions where GM cultivation could be prohibited for socio-economic reasons have not yet been set up. Certain regions have declared themselves to be GMO-free, but such declarations are of a political nature and do not constitute legally binding prohibitions. Some Member States provide for the possibility of designation of regions in which either only GM varieties of a given crop, or alternatively, only non-GM varieties can be cultivated on the basis of voluntary decisions by all farmers within the zone. An example of such a zone could be an area with a lot of seed production where the seed companies wish to have a high level of purity in their seeds and minimal to zero GM admixture.

The Commission report concludes that GM crop production in the EU is still a niche, with currently only a single GM product (GM maize MON810) being in commercial use and with cultivation on a very limited scale. About three quarters of the EU GM maize is produced in Spain, where it represents nearly one quarter of the national grain maize production area. Based on the limited commercial experience gained, there are no concrete indications of practical difficulties in introducing GM crops into EU agriculture. There have been no reports of economic damage resulting from either non-compliance with the national coexistence rules or from the rules themselves being inappropriate. There is no compelling evidence that differences in the legislative framework between Member States are a determining factor in the choice of farmers whether to grow GM crops or not. Other aspects, such as the existence of suitable market outlets, regional variation as regards advantages and disadvantages of GM crop production, and societal drivers are deemed to play a more important role. An updated report on the coexistence situation in EU Member States is expected in 2012.

The European Commission committed to establish guidelines for crop-specific coexistence measures and therefore created the European Coexistence Bureau (ECoB) in 2008, which is aimed at developing crop-specific Best Practice Documents for technical coexistence measures. The ECoB is located on the premises of the Joint Research Centre's Institute for Prospective Technological Studies (JRC-IPTS, Seville, Spain). Besides developing Best

Practice Documents, the ECoB will also address possible ways of minimising potential cross-border problems related to coexistence and develop recommendations for areas where agricultural structures and farming conditions are such that farm-level coexistence is difficult to achieve for a given crop (CEC, 2009).

7.7 The ECoB Best Practice Document on Coexistence in Maize Crop Production

The first (and thus far only) published ECoB Best Practice Document has focused on maize crop production (Czarnak-Klos et al., 2010). The following section provides an overview of the main messages from this first completed work of the ECoB published in 2010. The document reports consensually agreed best practices for coexistence of GM maize with conventional and organic maize, and intends to assist Member States in the development or refinement of their coexistence legislation or voluntary standards for good agricultural practice.

The report identifies possible sources of admixture during different levels of the production chain and relevant management practices to avoid admixture. It first identifies the presence of GM seeds in non-GM seed lots as one of the critical issues. It concludes that the most widely used coexistence measure is based on spatial isolation of GM and non-GM fields in order to limit cross-pollination between maize fields. Other common management practices to mitigate outcrossing are the use of pollen barriers or separation of flowering time. The recommended isolation distance in case of spatial isolation to limit the outcrossing to a level below the legally binding labelling threshold of 0.9% did not exceed 50 m. The report further recommends that in some cases (for example, fields located in close proximity to barren ground) isolation distance can be replaced by non-GM maize plants as buffer or discard zones. Such non-GM maize barriers (which are harvested and treated as GM plants) are usually more effective in reducing outcrossing levels than isolation distances.

The costs of the use of isolation distances basically correspond to so-called opportunity costs, i.e. costs related to not growing GM varieties on certain parts of the farm, and may depend on the regional conditions. In the case of isolation distance being replaced by a buffer zone, direct costs are incurred related to the sowing of two types of maize. A study of Gomez-Barbero (2008) based on a survey of commercial farms in three provinces of Spain during 2002-2004 reported that the impact of Bt maize adoption on gross margin ranged (depending on the province) from neutral to an increase of 122 euro/ha per year due to increased yields and reduced pesticide use. The ECoB document also reports costs of cleaning of machinery (38 euro for cleaning a seed driller; 56 euro for cleaning a combine harvester; 1.5 euro for cleaning a trailer or truck; plus 7 euro of labour cost per cleaning).

Following their review of published studies and available scientific evidence, the technical working group consensually agreed the following best practices:

- With respect to seed purity, seeds used should comply with the EU purity requirements and be segregated in a way that minimizes the risk of unintended use of GM varieties and commingling with non-GM varieties.

- The outcrossing of GM maize can be mitigated by applying appropriate spatial or temporal isolation measures. The spatial measures can be applied in all Member States. The use of temporal measures based on shifting the flowering times of GM and non-GM fields depends on the climatic conditions and is limited to Mediterranean countries and Romania. Minimum recommended sowing delays range from 15-20 days in Romania to 45-50 days in Greece, for example.

- Isolation distances were proposed separately for maize grain production and whole plant use. Maximum recommended isolation distance for an admixture level of 0.9% is 50 m.

- Buffer zones are considered a useful coexistence tool. The recommendation is to replace 2 m of isolation distance by 1 m of buffer.

- All machines, means of transport and storage places should be cleaned in an appropriate way in case the non-GM seeds or harvest were to be sown, harvested, transported or stored after the GM material. The use of dedicated machinery or storage places eliminates the risk of admixture.

The working group acknowledged that these recommendations may be difficult to apply in specific regions with smaller fields, elongated fields or short field depth. Alternative measures are proposed, such as communication between farmers to minimize problems including the establishment of voluntary agreements on labelling harvests as containing GMO and clustering of fields of one production system.

The practicality of coexistence in maize farming in Switzerland has been evaluated using statistical data on maize acreage and an aerial photographs assessment of the Swiss agricultural landscape by means of geographic information systems (GIS). This study showed that spatial resources would allow applying isolation distances for the cultivation of GM maize in the majority of the cases under actual Swiss agricultural conditions (Sanvido et al., 2007). In Swiss regions with a high ratio of maize cultivation within the arable land, however, it has been suggested that agreements between farmers will probably be necessary in half of the cases when implementing an isolation distance of 50 m.

7.8 Criticism of Coexistence in the EU

The regulations on the coexistence of GM and non-GM crops have been criticized as "a challenge that threatens to paralyze the cultivation of GM crops in Europe" (Devos et al., 2008); its associated debate as "going to ridiculous lengths" (Ramessar et al., 2010); and the resulting strict regulations as "reducing social welfare and limiting further innovation within European agriculture" (Mosher & Hurburgh, 2010). Ramessar et al. (2010) postulate that "even if a GM crop can surmount Europe's excessive product registration process, any farmer hoping to plant it must then navigate tortuous, arbitrary and scientifically unjustifiable coexistence regulations". They describe the EU coexistence policy as a haphazard and inconsistent set of rules that has no rational scientific underpinning, which obstructs GM producers, misleads the public and adds unnecessary layers of complexity to international trade.

The main point of critique pertains to the establishment of wide and fixed isolation distances, which according to Devos et al. (2008) fail to satisfy four important challenges. First, they are inappropriate in many cases since they are excessive from a scientific point of view. Second, they are difficult to implement in practice without jeopardizing farmers' freedom of choice, especially in areas where maize is grown on a substantial part of the agricultural area and/or where maize fields are small and scattered. Third, they are inconsistent with regional heterogeneity of farming including cropping patterns, field and landscape characteristics and distribution. Fourth, they are not proportional to the economic incentives for coexistence such as potential GM or GM-free gains and possible price premiums determined by the local market conditions.

The EU-funded SIGMEA project (Messean et al., 2009) presented a range of measures that could be adopted based on decisions made at the local level which consider landscape factors such as farm and field size, the proportion of GM and non-GM crops of the same species and the methods of post market handling of the crops (e.g. commercialization through cooperatives or merchants). SIGMEA recommended that measures adopted should be flexible and proportionate and argued against the introduction of rigid regulations and high isolation distance requirements.

However, the minimum distance requirements included in most of the EU Member States' coexistence policies discriminate against smaller farms, which has implications for the distribution of GM adopting farms. Areas with, on average, smaller farm and field sizes will experience lower rates of adoption and a reduction of their competitiveness (Beckmann et al., 2010). A possible corner solution for those areas is that either all farmers adopt the technology or none, i.e. in the latter case the zone becomes a GM-free zone. Beckmann et al. (2010) also show that regulatory choices have implications for the comparative advantage as opportunity costs change; in cases where the comparative advantage is with the GM farmer, the GM farmer may outcompete the non-GM farmer. Following their economic analysis, the authors suggest a combination of ex-ante regulations and ex-post liability rules as a superior model over ex-ante regulations only, except for the trivial case where ex-ante regulations would envisage to stop GM crop production at all. In a similar vein, Devos et al. (2008) referred to "the irony of the adopted EU coexistence policy": whereas it initially contributed to the lifting of the EU moratorium on GMOs, it is currently placing another barrier on the path of GM crops through imposing wide and fixed isolation distances as the principal ex-ante preventive measure.

In addition, according to Mosher and Hurburgh (2010) current coexistence measures within the EU have placed the responsibility for the segregation procedures with GM crop producers as users of the technology in question. This mode of regulation places additional liability on innovators within the market, thereby reducing social welfare and limiting further innovation. Negative impacts on welfare stem from heavy regulation, uncertain consumer demand and unknown incentives for differentiated products in the marketplace. The authors refer to the alternative of a more flexible system of regulation allowing for the heterogeneous environment in European agriculture, which would open up for greater gains in innovation and welfare. Also Devos et al. (2008) call for allowing flexibility in ex ante coexistence regulations to enable regionally and economically proportionate coexistence. This might be achieved by allowing plural coexistence measures that are adaptable to local farming and cropping conditions, and that are negotiable among farmers, i.e. a plea to build in flexibility in national/regional coexistence regulations.

7.9 Experiences from Portugal

Portugal has a complete system of coexistence regulation with compulsory training courses, strict anti-cross-pollination measures and a public compensation fund (Ramessar et al., 2010), but its system allows some of the flexibility as called for in the criticism on coexistence in the EU.

Farmers who intend to grow GM maize in Portugal must attend mandatory training courses in order to be informed about the coexistence of GM, conventional and organic crops. The courses are provided by seed companies or farmers' organisations and their content is evaluated and supervised by the Portuguese Directorate General for Crop Production from the Ministry of Agriculture (Skevas et al., 2010). Farmers must notify GM crop cultivations (in terms of variety, area, place and intended coexistence measures) to the regional agricultural authority, and inform by letter their immediate neighbours and the operators with whom they share agricultural machinery. They also have to cooperate with agricultural authorities in all control and monitoring actions by means of record keeping of their production process (Quedas & Carvalho, 2011).

The Portuguese law also establishes ex-post liability provisions, including a compensation fund financed through a 4 euro tariff on the price for standard GM seed bags, and penalties for farmers who do not comply with the coexistence rules. Interestingly, the main seed providing company has agreed to pay for any damage due to accidental cross-pollination, as well as due to vandalism or destruction of the crops by GM opponents.

Technical segregation measures in Portugal include isolation distances to non-GM crops of the same species (200 m for conventional and 300 m for organic maize plots), barriers, buffer zones, temporal production planning (at least 20 days difference in flowering times), and seed handling and storage guidelines. As an alternative to the use of isolation distances, different times for seeding or the use of a 20% buffer zone which at the same time can be part of the refuge zone for pest resistance management can be chosen by farmers (Skevas et al., 2010). In compliance with the Portuguese law of coexistence, a single municipality (Lagos, Algarve) has been recognized a GM free zone, and Madeira has been the first GM free region in the EU (Quedas & Carvalho, 2011).

Even though the Portuguese system of coexistence is quite complete and strict, it still allows some flexibility in isolation measures depending on voluntary agreements among neighbours. Technical segregation measures are mandatory but can be amended according to local conditions. The Portuguese regulations explicitly provide the opportunity to reduce the coexistence compliance costs through collaboration, e.g. the voluntary grouping of farmers to create production zones exclusively dedicated to the cultivation of GM varieties deriving from the same GMO. Coexistence measures are only expected between the production zone farmers and their neighbours outside the production zone. This kind of collective initiative avoids complicated anti-cross-pollination measures and expensive duplication of farming operations and facilities (Ramessar et al., 2010).

A case study of five Bt maize producers who are members of the same cooperative showed that coexistence regulations as established in Portugal do not necessarily lead to increased production costs, provided these regulations are flexible enough (Skevas et al., 2010). The proximity of the fields of the group members in conjunction with the lack of conventional and/or organic maize neighbours enabled them to avoid the use of segregation distances. Low ex-ante coexistence compliance costs, combined with reduced uncertainty owing to the compensation fund for accidental cross-pollination and the provision of compensation for eventual crop destruction provided a strong incentive for the farmers for adopting Bt maize production. The fact that the group of farmers existed for more than seven years, which allowed them to get to know each other and develop trust facilitated the reaching of a voluntary agreement. The case study as documented by Skevas et al. (2010) demonstrates that flexible ex-ante regulation combined with clear ex-post liability rules can prove beneficiary for the effective implementation of coexistence regulations in Europe.

Based on five years of experience with coexistence in Portugal, Quedas and Carvalho (2011) concluded that Portuguese maize growers have so far experienced coexistence as feasible and useful. Nevertheless, the adoption rate of Bt maize is still low (4%). The voluntary establishment of production zones makes coexistence easier and enables small farms to adopt Bt maize varieties. Challenges identified pertain to: (1) the possible effects of policies that positively discriminate non-GM farmers (e.g. subsidy provisions can limit the adoption of GM varieties and the establishment of production zones, leading to negative discrimination of small farms regarding the adoption of GM crops), (2) a growing interest in conservation agriculture combined with the availability of herbicide tolerant crops and varieties and the new issues this may raise with respect to coexistence, and (3) further research dealing with pest insect population dynamics, cost-benefit analyses of coexistence and gene flow modelling.

8. Conclusions

The psychological part of the present review has focused on the cognitive representation of gene technology and its applications in food and agriculture among members of the general public, and on the processes by which members of the general public construct their evaluations. The evidence reviewed in this part suggests the following preliminary conclusions:

- Gene technology and its applications in food and agriculture are only sparsely represented in people's thoughts and memory. Evaluations of the technology and its applications are not to a significant degree based on learned associations. Rather, evaluations are constructed on the spot through conscious, propositional reasoning.

- In these reasoning processes, members of the general public set gene technology in relation to other, more abstract and general attitude objects. The most important ones are the environment, technological progress, and the trustworthiness of the actors and institutions involved with the technology and its applications.

In the second part of the present review, we discussed trends in public opinion in the region immediately surrounding Switzerland. The discussion was mainly based on the results of the Special Eurobarometer surveys that are conducted in three-year intervals on behalf of the European commission. The results can be summarised as follows:

- The average attitudes of EU citizens tend to follow the general tone of the public debate. In the early 1990s, EU citizens were predominantly optimistic about future impacts of biotechnology. During the crisis that culminated in the EU moratorium, attitudes took a sceptical turn. Since then, EU citizens have more optimistic again, reaching at a level comparable to that of the early 1990s

- At present, the average attitudes of EU citizens towards gene technology and its applications in food and agriculture vary from neutral to slightly negative, depending on the respective application. Furthermore, the attitudes of EU citizens show systematic association with gender and age. Men tend to report more positive attitudes than women, and younger people tend to report more positive attitudes than older people.

In the third part of the present review, the potential influence of gene technology on the actual purchasing behaviour of consumers was discussed. Due to the very limited levels of consumer attention to information on food packages, the preliminary conclusion from this section is that no substantial effects of GM labels can be expected.

The agricultural economics part of this review has concentrated on the positions taken by different stakeholders involved in the agro-food chain, on the value and benefit sharing of agricultural biotechnologies, and on the economic incentives and costs of coexistence. This review has yielded the following conclusions, each of which deserve to be scrutinised in the specific Swiss agricultural context:

- The position of industry and retailers towards incorporating GM products in their assortments is guided by market demand forces, specifically anticipated consumer reactions and demand factors. Fear for loss of market value in the case of GM labelling and loss of corporate image in case of negative publicity following the adoption of GM products are important motives. Stakeholder workshops and interviews within the Co-Extra project have revealed that industries are either unaware about costs of traceability and coexistence, or unwilling to share this information.

- Several studies point to gaps in the understanding of the relevance of farmers' positions towards agricultural biotechnologies. Most importantly, farmers are to be recognised as a heterogeneous group, both with respect to their attitudes towards agricultural biotechnologies, as well as with respect to the potential benefits they can realise from adopting GM crops. GM adopters seem to be concerned about the social impacts of their GM adoption decisions, and not only driven by economic incentives. Farmers seem particularly reluctant to additional administrative burdens that may come along with permissions to grow GM crops.

- Important factors shaping farmers' position towards agricultural biotechnologies pertain to farm characteristics (especially farm size or operating scale) as well as individual farmer characteristics such as their type of knowledge and first-hand experience with agricultural biotechnologies. In general, farmers are the major beneficiaries of agricultural biotechnologies, skimming generally about two thirds of the benefits of GM. From a policy perspective, it is crucial to consider the benefits foregone for this particular farmer stakeholder group in case of non-adoption of GM.

- Interactions between the different stakeholders involved in the agro-food chain are poorly studied thus far and little is known about the impact of chain relationships in shaping positions towards agricultural biotechnologies.

- The ex ante estimated values of agricultural biotechnologies are substantial. Generally, benefits from agricultural biotechnologies are shared two thirds downstream the chain (farmers, industry, retailers, consumers) versus one third upstream the chain (gene developers and seed multinationals). The distribution of the downstream benefits (especially whether consumers benefit directly, indirectly or not at all) largely depends on the agricultural policy and internal market organisation in the considered country or region.

- Coexistence with wide fixed isolation distances imposes four challenges to policy makers: (1) defining appropriateness of isolation distances, (2) feasibility of isolation distances without jeopardising farmers' freedom of choice, (3) accounting for regional heterogeneity of farming, and (4) proportionality to economic incentives.

- Strong market signals are a precondition for coexistence. This includes that consumer should (1) have strong and sustainable preferences for non-GM products, and (2) are willing to pay significant price premiums for it. In markets where consumers are unwilling to pay premium prices for GM-free products, there is no coexistence issue stricto sensu from an economic incentives' perspective.

- In the specific case of Swiss farmers, the study by Wolf and Vögele (2009) suggests that the cultivation of Bt corn becomes economically viable compared to the cultivation of non-GM maize once there is a light-to-moderate (10-25%) corn-borer infestation, provided that the seed premium does not exceed 25%. For small Swiss farmers with less than 25 ha arable land, the cultivation of Bt corn is only profitable if the corn-borer infestation is strong.

- The EU coexistence policy, with mandatory GM labelling of products that exceed the 0.9% admixture threshold, follows a subsidiarity principle, which means that the development of specific legislation and non-binding coexistence guidelines is the competence of individual EU Member States. As a result, different national and/or regional coexistence regulations have been established that combine different kinds and levels of ex-ante regulations with ex-post liability rules.

- The recently established European Bureau for Coexistence (ECoB) is expected to produce best practice documents for the coexistence of genetically modified crops with conventional and organic farming, and issued its first report in 2010 on maize crop production. The ECoB document recommends concrete isolation distances – the most common but criticized ex-ante regulation measure – in order to achieve admixture due to cross pollination at levels from less than 0.1% to the threshold level of 0.9%.

- The criticism on EU coexistence in general, and the wide and fixed isolation distances as used in several Member States in particular, holds that the proposed measures are too often not scientifically justified, difficult to implement, inconsistent and not proportional, and thus can be interpreted as a return or continuation of the lifted moratorium in many cases.

- Building in flexibility in national/regional coexistence regulations depending on local farming and cropping conditions and allowing for negotiation space and voluntary agreements between farmers, has been called for. Experiences from Portugal demonstrate that a combination of flexible ex-ante regulations and clear ex-post liability rules that reduce uncertainties and foster the establishment of voluntary agreement between neighbouring farmers. A study under typical Swiss agricultural landscape conditions confirms that a coexistence policy with isolation distances for maize complemented by agreements among farmers is feasible in practice. A flexible approach and a minimal dose of willpower prove beneficial for the effective implementation of coexistence regulations in Europe, thus enabling free choice for consumers and producers in line with their individual preferences and economic opportunities.

9. References

Aerni, P., Scholderer, J. & Ermen, D. (2011). How would Swiss consumers decide if they had freedom of choice? Evidence from a field study with organic, conventional and GM corn bread. *Food Policy, 36,* 830-838.

Bagchi-Sen, S. & Scully, J. (2007). Strategies and external relationships of small and medium-sized enterprises in the US agricultural biotechnology sector. *Environment and Planning C – Government and Policy, 25,* 844-860.

Bauer, M. W. & Bonfadelli, H. (2002). Controversy, media coverage and public knowledge. In M. W. Bauer & G. Gaskell (Eds.), *Biotechnology: The making of a global controversy* (pp. 149-178). Cambridge: Cambridge University Press.

Beckmann, V., Soregaroli, C. & Wesseler, J. (2010). Ex-ante regulation and ex-post liability under uncertainty and irreversibility: Governing the coexistence of GM crops. Economics 4 (2010): 9.

Bertheau, Y. (2009). Summary of main Co-Extra deliverables & results, perspectives, information dissemination & application. In: Co-Extra (2009). GM and non-GM supply chains: Their co-existence and traceability. Abstracts of the Co-Extra International Conference, 2-5 June 2009, Paris, pp. 79-95. http://www.coextra.eu

Binimelis, R. (2008). Coexistence of plants and coexistence of farmers: Is an individual choice possible? *Journal of Agricultural & Environmental Ethics, 21,* 437-457.

Bonfadelli, H. (2010). Die grüne Gentechnologie im Urteil der Schweizer Bevölkerung: Wissen, Akzeptanz, Bewertung. In H. Bonfadelli & W. A. Meier (Eds.), *Grüne Gentechnologie im öffentlichen Diskurs: Interessen, Konflikte und Argumente* (pp. 181-232). Konstanz: UVK.

Borre, O. (1990). Public opinion on gene technology in Denmark 1987 to 1989. *Biotech Forum Europe, 7,* 471-477.

Bredahl, L. (1999). Consumers' cognitions with regard to genetically modified food. Results of a qualitative study in four countries. *Appetite, 33*, 343-360.

Bredahl, L. (2001). Determinants of consumer attitudes and purchase intentions with regard to genetically modified foods: Results of a cross-national survey. *Journal of Consumer Policy, 24*, 23-61.

Brookes, G. (2005). The farm-level impact of herbicide-tolerant soybeans in Romania. *AgBioForum, 8,* 235-241.

Brüggemann, A., & Jungermann, H. (1998). Abstrakt oder konkret: Die Bedeutung der Beschreibung von Biotechnologie für ihre Beurteilung. *Zeitschrift für Experimentelle Psychologie, 45*, 303-318.

Carter, C. A. & Gruère, G. P. (2003). Mandatory labelling of genetically modified foods: does it really provide consumer choice? *AgBioForum, 6,* 68-70.

Chong, M. (2005). Perception of the risks and benefits of Bt eggplant by Indian farmers. *Journal of Risk Research, 8,* 617-634.

Commission of the European Communities (CEC) (2009). Report from the Commission to the Council and the European Parliament on the coexistence of genetically modified crops with conventional and organic farming. SEK(2009) 408. Brussels: Commission of the European Communities.

Connor, M. & Siegrist, M. (2010). Factors influencing people's acceptance of gene technology: The role of knowledge, health expectations, naturalness, and social trust. *Science Communication, 32*, 514-538.

Connor, M. & Siegrist, M. (2011). The power of association: Its impact on willingness to buy GM food. *Human and Ecological Risk Assessment, 17*, 1142-1155.

Conrey, F. R. & Smith, E. R. (2007). Attitude representation: Attitudes as patterns in a distributed, connectionist representation system. *Social Cognition*, *25,* 718-735.

Cowburn, G. & Stockley, L. (2005). Consumer understanding and use of nutrition labelling: a systematic review. *Public Health Nutrition, 8,* 21-28.

Custers, R., Sakelaris, G., Sweet, J., Minol, K., Sinemus, K., Milavec, M., Jansen, A. & Cheneval, M. (2009). Stakeholder views in EU. In: Co-Extra (2009). GM and non-GM supply chains: Their coexistence and traceability. Abstracts of the Co-Extra International Conference, 2-5 June 2009, Paris, p. 62. http://www.coextra.eu

Czarnak-Klos, M. & Rodriguez-Cerezo, E. (2010). European Coexistence Bureau Best Practice Documents for coexistence of genetically modified crops with conventional and organic farming: 1. Maize crop production. EUR 24509 EN. Seville: European Commission, Joint Research Centre, Institute for Prospective Technological Studies.

Dannenberg, A. (2009). The dispersion and development of consumer preferences for genetically modified food – A meta-analysis. *Ecological Economics, 68,* 2182-2192.

Dean, M., & Shepherd, R. (2007). Effects of information from sources in conflict and in consensus on perceptions of genetically modified food. *Food Quality and Preference, 18,* 460-469.

Demont, M. & Devos, Y. (2008). Regulating coexistence of GM and non-GM crops without jeopardizing economic incentives. *Trends in Biotechnology, 26,* 353-358.

Demont, M. & Dillen, K. (2008). Herbicide tolerant sugar beet: The most promising first-generation GM crop? *International Sugar Journal, 110,* 613-617.

Demont, M. & Tollens, E. (2004). Ex ante welfare effects of agricultural biotechnology in the European Union: the case of transgenic herbicide tolerant sugarbeet. In: Evenson, R.E. & Santaniello, V. (eds.), The *Regulation of Agricultural Biotechnology* (pp. 239-255). Wallingford: CABI.

Demont, M. & Tollens, E. (2004). First impact of biotechnology in the EU: Bt maize adoption in Spain. *Annals of Applied Biology, 145,* 197-207.

Demont, M. et al. (2004). Biodiversity versus transgenic sugar beet: the one euro question. *European Review of Agricultural Economics, 31,* 1-18.

Demont, M. et al. (2007). GM crops in Europe: How much value and for whom? *EuroChoices, 6,* 46-53.

Demont, M. et al. (2008a). Ex ante impact assessment under imperfect information: biotechnology in New Member States of the EU. *Journal of Agricultural Economics, 59,* 463-486.

Demont, M. et al. (2008b). Regulating coexistence in Europe: Beware of the domino-effect! *Ecological Economics, 64,* 683-689.

Demont, M. et al. (2009). Towards flexible coexistence regulations for GM crops in the EU. *EuroChoices* (in press).

Devos, Y., Demont, M. & Sanvido, O. (2008). Coexistence in the EU – return of the moratorium on GM crops? Nature Biotechnology 26: 1223-1225.

Devos, Y., Demont, M., Dillen, K., Reheul, D., Kaiser, M. & Sanvido, O. (2009). Coexistence of genetically modified (GM) and non-GM crops in the European Union. A review. Agronomy for Sustainable Development 29: 11-30.

Devos, Y. et al. (2008). Coexistence in the EU – return of the moratorium on GM crops? *Nature Biotechnology, 26,* 1223-1225.

Devos, Y. et al. (2009). Coexistence of genetically modified (GM) and non-GM crops in the European Union. A review. *Agronomy for Sustainable Development, 29,* 11-30.

Dillen et al. (2009). Global welfare effects of GM sugar beet under changing EU sugar policies. *AgBioForum, 12,* 1-11.

Dillen, K. et al. (2008). European sugar policy reform and agricultural innovation. *Canadian Journal of Agricultural Economics, 56,* 533-553.

European Commission (1997). *Eurobarometer 46.1: Europeans and modern biotechnology.* Luxembourg: Office for Official Publications of the European Communities.

Fazio, R. H. (2007). Attitudes as object-evaluation associations of varying strength, *Social Cognition*, *25*, 603-637.

Finucane, M. L. & Holup, J. L. (2005). Psychosocial and cultural factors affecting the perceived risk of genetically modified food: An overview of the literature. *Social Science and Medicine, 60,* 1603-1612.

Frewer, L. J., Hedderley, D., Howard, C., & Shepherd, R. (1997). “Objection” mapping in determining group and individual concerns regarding genetic engineering. *Agriculture and Human Values*, *14*, 67-79.

Frewer, L. J., Howard, C., Hedderley, D., & Shepherd, R. (1999). Reactions to information about genetic engineering: impact of source characteristics, perceived personal relevance, and persuasiveness. *Public Understanding of Science, 8,* 35-50.

Frewer, L. J., Howard, C., & Shepherd, R. (1998). The influence of initial attitudes on responses to communication about genetic engineering in food production. *Agriculture & Human Values, 15,* 15-30.

Frewer, L. J., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., & Berdal, K. G. (2004). Societal aspects of genetically modified foods. *Food and Chemical Toxicology, 42,* 1181-1193.

Frewer, L. J., Miles, S., & Marsh, R. (2002). The GM foods controversy. A test of the social amplification of risk framework. Risk Analysis, 22, 701-711.

Frewer, L. J., Scholderer, J. & Bredahl, L. (2003). Communicating about the risk and benefits of genetically modified foods: The mediating role of trust. *Risk Analysis, 23*, 1117-1133.

Furtan, W. H. et al. (2007). Landscape clubs: Coexistence of genetically modified and organic crops. *Canadian Journal of Agricultural Economics, 55,* 185-195.

Gaskell, G., Allansdottir, A., Allum, N., Corchero, C., Fischler, C., Hampel, J., Jackson, J., Kronberger, N., Mejlgaard, N., Revuelta, G., Schreiner, C., Torgersen, H., & Wagner, W. (2006). *Europeans and Biotechnology in 2005: Patterns and Trends* (Final report on Eurobarometer 64.3). Luxembourg: Office for Official Publications of the European Communities.

Gaskell, G., Allum, N., & Stares, S. (2003). *Eurobarometer 58.0: Europeans and biotechnology in 2002.* Luxembourg: Office for Official Publications of the European Communities.

Gaskell, G., Stares, S., Allansdottir, A., Allum, N., Castro, P., Esmer, Y., Fischler, C., Jackson, J., Kronberger, N., Hampel, J., Mejlgaard, N., Quintanilha, A., Rammer, A., Revuelta, G., Stoneman, P., Torgersen, H., & Wagner, W. (2010). European and biotechnology in 2010: Winds of Change? Luxembourg: Office for Official Publications of the European Union.

Gawronski, B. & Bodenhausen, G. V. (2006). Associative and propositional processes in evaluation: An integrative review of implicit and explicit attitude change. *Psychological Bulletin*, *132,* 692-731.

Gawronski, B. & Bodenhausen, G. V. (2007). Unraveling the processes underlying evaluation: Attitudes from the perspective of the APE model. *Social Cognition*, *25,* 687-717.

Gomez-Barbero et al. (2008). Bt corn in Spain: the performance of the EU’s first GM crop. *Nature Biotechnology, 26,* 384-386.

Gomez-Barbero, M., Berbel, J. & Rodriguez-Cerezo, E. (2008). Adoption and performance of the first GM crop introduced in EU agriculture: Bt maize in Spain. EUR 22778 EN. Seville: European Commission, Joint Research Centre.

Gruère, G. P. (2006). A preliminary comparison of the retail level effects of genetically modified food labelling policies in Canada and France. *Food Policy, 31,* 148-161.

Grunert, K. G., Lähteenmäki, L., Nielsen, N. A., Poulsen, J. B., Ueland, O., & Åström, A. (2001). Consumer perceptions of food products involving genetic modification: Results from a qualitative study in four Nordic countries. *Food Quality and Preference, 12,* 527-542.

Grunert, K. G. & Wills, J. M. (2007). A review of European research on consumer response to nutrition information on food labels. *Journal of Public Health.15,* 385-399.

Grunert, K. G. & Wills, J. M. (2009). *Pan-European consumer research on in-store behaviour, understanding and use of nutrition information on food labels, and nutrition knowledge*. Brussels: EUFIC.

Guehlstorf, N. P. (2008). Understanding the scope of farmer perceptions of risk: Considering farmer opinions on the use of genetically modified (GM) crops as stakeholder voice in policy. *Journal of Agricultural & Environmental Ethics, 21,* 541-558.

Gutteling, J. M., Olofsson, A., Fjæstad, B., Kohring, M., Goerke, A., *et al.* (2002). Media coverage 1973-1996: Trends and dynamics. In M. W. Bauer & G. Gaskell (Eds.), *Biotechnology: The making of a global controversy* (pp. 95-128). Cambridge: Cambridge University Press.

Hagemann, K. S. & Scholderer, J. (2009). Hot potato: Expert-consumer differences in the perception of a second-generation novel food. *Risk Analysis* (in press).

Hall, C. (2008). Identifying farmer attitudes towards genetically modified (GM) crops in Scotland: Are they pro- or anti-GM? *Geoforum, 39,* 204-212.

Hamstra, A. (1998). *Public opinion about biotechnology. A survey of surveys*. The Hague: European Federation of Biotechnology.

Hamstra, A. M. (1991). *Biotechnology in foodstuffs. Towards a model of consumer acceptance*. The Hague: The Swoka Institute.

Hamstra, A. M. (1995). *Consumer acceptance model for food biotechnology: Final report*. The Hague: The SWOKA Institute.

Hamstra, A. M. & Feenstra, M. H. (1989). *Consument en biotechnologie. Kennis en meningsvorming van consumenten over biotechnologie* (SWOKA onderzoeksrapport nr.85). Den Haag: SWOKA.

Hamstra, A. M., & Smink, C. (1996). Consumers and biotechnology in the Netherlands. British Food Journal, 98, 34-38.

Heller, C. (2007). Techne versus technoscience: Divergent (and ambiguous) notions of food “Quality” in the French debate over GM crops. *American Anthropologist, 109,* 603-615.

INRA Europe (1991). *Eurobarometer 34.1: Opinions of Europeans on biotechnology in 1991.* Luxembourg: Office for Official Publications of the European Communities.

INRA Europe (1993). *Eurobarometer 39.1: Biotechnology and genetic engineering – What Europeans think about it*. Luxembourg: Office for Official Publications of the European Communities.

INRA Europe (2000). *Eurobarometer 52.1: The Europeans and Biotechnology.* Luxembourg: Office for Official Publications of the European Communities.

James, C. (2003). *Global status of commercialised transgenic crops: 2003 – Preview* (ISAAA Briefs No. 30). Ithaca, NY: ISAAA.

Joly, P. B. & Assouline, G. (2001). *Assessing public debate and participation in technology assessment in Europe* (Report to the European Commission). Grenoble: INRA.

Kaup, B. Z. (2008). The reflexive producer: The influence of farmer knowledge upon the use of Bt corn. *Rural Sociology, 73,* 62-81.

Knight, J. G., Mather, D. W., & Holdsworth, D. K., and Ermen, D. F. (2007). Acceptance of GM food – an experiment in six countries. *Nature Biotechnology, 25,* 507-508.

Kondoh, K. & Jussaume, R. A. (2006). Contextualizing farmers’ attitudes towards genetically modified crops. *Agricultural and Human Values, 23,* 341-352.

Krishna, V. V. & Qaim, M. (2007). Estimating the adoption of Bt eggplant in India: Who benefits from public-private partnership? *Food Policy, 32,* 523-543.

Kurzer, P. & Cooper, A. (2007). What’s for dinner? – European farming and food traditions confront American biotechnology. *Comparative Political Studies, 40,* 1035-1058.

Levidow, L., Carr, S. & Wield, D. (2000). Genetically modified crops in the European Union: Regulatory conflict and precautionary opportunities. *Journal of Risk Research, 3,* 189-208.

Lin, W., Tuan, F., Dai, Y., Zhong, F., & Chen, X. (2008). Does biotech labelling affect consumers’ purchasing decisions? A case study of vegetable oils in Nanjing, China. *AgBioForum, 11,* 123-133.

Lusk, J. L., Jamal, M., Kurlander, L., Roucan, M., & Taulman, L. (2005). A meta-analysis of genetically modified food valuation studies. Journal of Agricultural and Resource Economics, 30, 28-44.

Marks, L. A., Kalaitzandonakes, N., & Vickner, S. (2004). Consumer purchasing behavior toward GM foods in Europe. In R. Evenson & V. Santaniello (Eds.), *Consumer acceptance of biotech foods* (pp. 23-39). Wallingford: CABI.

Mather, D., Knight, J., & Holdsworth, D. (2005). Pricing differentials for organic, ordinary and genetically modified food. *Journal of Product & Brand Management, 14*(6), 387-392.

Mauro, I. J. & McLachlan, S. M. (2008). Farmer knowledge and risk analysis: Postrelease evaluation of herbicide-tolerant canola in western Canada. *Risk Analysis, 28,* 463-476.

Menrad, K., & Gabriel, A. (2009). Costs and benefits of segregation and traceability between GM and non-GM supply chains of final food products. In: Co-Extra (2009). GM and non-GM supply chains: Their co-existence and traceability. Abstracts of the Co-Extra International Conference, 2-5 June 2009, Paris, pp. 30-32. http://www.coextra.eu

Menrad, K., Gabriel, A. & Gylling, M. (2009). Costs of coexistence and traceability systems in the food industry in Germany and Denmark. In: Co-Extra (2009). GM and non-GM supply chains: Their co-existence and traceability. Abstracts of the Co-Extra International Conference, 2-5 June 2009, Paris, p. 138. http://www.coextra.eu

Messéan, A., Squire, G., Perry, J., Angevin, F., Gomez, M., Townend, P., Sausse, C., Breckling, B., Langrell, S., Dzeroski, S. & Sweet, J. (2009). Sustainable introduction of GM crops into European agriculture: a summary report of the FP6 SIGMEA research project. Oléagineux, Corps Gras et Lipides 16: 37-51.

Midden, C., Boy, D., Einsiedel, E., Fjæstad, B., Liakopoulos, M., et al. (2002). The structure of public perceptions. In M. W. Bauer & G. Gaskell (Eds.), *Biotechnology: The making of a global controversy* (pp. 203-224). Cambridge: Cambridge University Press.

Miles, S., & Frewer, L. J. (2001). Investigating specific concerns about different food hazards. *Food Quality and Preferences, 12*, 47-61.

Miles, S., Ueland, Ø., & Frewer, L. J. (2005). Public attitudes towards genetically modified food. *British Food Journal, 107,* 246-242.

Mosher, G. & Hurburgh, C. (2010). Transgenic plant risk: coexistence and economy. Encyclopedia of Biotechnology in Agriculture and Food 1: 639-642.

Noomene, R. & Gil, J. M. (2007). GM food and the Spanish consumer. *ITEA – Informacion Tecnica Economica Agraria, 103,* 127-155.

Noussair, C., Robin, S., & Ruffieux, B. (2002). Do consumers not care about biotech foods or do they just not read the labels? *Economics Letters, 75*, 47-53.

Noussair, C., Robin, S., & Ruffieux, B. (2004). Do consumers really refuse to buy genetically modified food? *Economic Journal, 114*, 102-120.

Peters, H. P. (2000). The committed are hard to persuade: Recipients' thoughts during exposure to newspaper and TV stories on genetic engineering and their effect on attitudes. *New Genetics & Society, 19,* 367-383.

Poortinga, W., & Pidgeon, N. F. (2004). Trust, the asymmetry principle, and the role of prior beliefs. *Risk Analysis, 24*, 1475-1486.

Poortinga, W., & Pidgeon, N. F. (2005). Trust in Risk Regulation: Cause or Consequence of the Acceptability of GM Food? *Risk Analysis, 25*, 199-209.

Poortinga, W., & Pidgeon, N. F. (2006). Prior Attitudes, Salient Value Similarity, and Dimensionality: Toward an Integrative Model of Trust in Risk Regulation. *Journal of Applied Social Psychology, 36*, 1674-1700.

Qin, W., & Brown, J. L. (2007). Public reactions to information about genetically engineered foods: Effects of information formats and male/female differences. *Public Understanding of Science, 16,* 471-488.

Quedas, M. F. & Carvalho, P. C. (2011). A quinquennium of coexistence in Portugal. Paper presented at: GMCC11, 26-28 October 2011, Vancouver, Canada.

Ramessar, K., Capell, T., Twyman, R.M. & Christou, P. (2010). Going to ridiculous lengths – European coexistence regulations for GM crops. Nature Biotechnology 28: 133-136.

Saba, A., & Vassallo, M. (2002). Consumer attitudes toward the use of gene technology in tomato production. *Food Quality and Preference, 13*, 13-21.

Sanvido, O, Widmer, F., Winzeler, M., Streit, B., Szerencsits, E. & Bigler, F. (2008). Definition and feasibility of isolation distances for transgenic maize cultivation. Transgenic Research 17: 317-335.

Scholderer, J. (2005). The GM foods debate in Europe: History, regulatory solutions, and consumer response research. *Journal of Public Affairs, 5,* 263-274.

Scholderer, J., Balderjahn, I., Bredahl, L. & Grunert, K. G. (1999). The perceived risks and benefits of genetically modified food products: Experts versus consumers. *European Advances in Consumer Research, 4,* 123-129.

Scholderer, J., & Frewer, L. (2003). The biotechnology communication paradox: Experimental evidence and the need for a new strategy. *Journal of Consumer Policy, 26,* 125-157.

Scholderer, J. & Hagemann, K. (2006). *Consumer attitudes towards the risks and benefits of novel foods* (MAPP project paper no. 03/06). Aarhus: Aarhus School of Business.

Scholderer, J., Hagemann, K., Sørensen, B. T., & Czienskowski, U. (2007). *Consumer use of information about novel foods and novel food technologies* (MAPP project paper no. 01/07). Aarhus: Aarhus School of Business.

Schütz, H., Wiedemann, P. M., & Gray, P. C. R. (1999). Die intuitive Beurteilung gentechnischer Produkte: Kognitive und interaktive Aspekte. In J. Hampel & O. Renn (Eds.), *Gentechnik in der Öffentlichkeit: Wahrnehmung und Bewertung einer umstrittenen Technologie* (pp. 133-169). Frankfurt/Main: Campus.

Schwarz, N. (2007). Attitude construction: Evaluation in context. *Social Cognition, 25,* 638-656.

Seifert, F. (2008). Consensual resistance and farmers' protest against globalisation – Resistance against agrarian (green) biotechnology in Austria and France. *SWS-Rundschau, 48,* 485-504.

Siegrist, M. (1998). Belief in gene technology: The influence of environmental attitudes and gender. *Personality and Individual Differences, 24,* 861-866.

Siegrist, M. (1999). A causal model explaining the perception and acceptance of gene technology. *Journal of Applied Social Psychology, 29,* 2093-2106.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20*, 195-204.

Skevas, T., Fevereiro, P. & Wesseler, J. (2010). Coexistence regulations and agriculture production: A case study of five Bt maize producers in Portugal. Ecological Economics 69: 2402-2408.

Smyth, S. et al. (2002). Liabilities and economics of transgenic crops. *Nature Biotechnology, 20,* 537-541.

Søndergaard, H. A., Grunert, K. G. & Scholderer, J. (2007). Consumer attitudes towards novel enzyme technologies in food processing. In B. Rastall (Ed.), *Novel enzyme technology for food applications* (pp. 85-97). Cambridge: Woodhead Publishing.

Sparks, P., Shepherd, R., & Frewer, L. J. (1994). Gene technology, food production, and public opinion: A UK study. *Agriculture and Human Values, 11(1),* 19-28.

Sparks, P., Shepherd, R., & Frewer, L. J. (1995). Assessing and structuring attitudes toward the use of gene technology in food production: The role of perceived ethical obligation. *Basic and Applied Social Psychology, 16*(3), 267-285.

Spence, A. & Townsend, E. (2006). Examining consumer behaviour towards genetically modified (GM) food in Britain. *Risk Analysis, 26,* 657-670

Spence, A. and Townsend, E. (2006). Implicit attitudes towards genetically modified (GM) foods: A comparison of context-free and context-dependent evaluations. *Appetite, 46,* 67-74

Spence, A. & Townsend, E. (2007). Predicting behaviour towards Genetically Modified (GM) food using implicit and explicit attitudes. *British Journal of Social Psychology 46, (2),* 437-457.

Tenbült, P., de Vries, N. K., Dreezens, E., & Martijn, C. (2005). Perceived naturalness and acceptance of genetically modified food. *Appetite, 45*, 47-50.

Tenbült, P., De Vries, N. K., Dreezens, E., & Martijn, C. (2008). Intuitive and explicit reactions towards "new" food technologies: Attitude strength and familiarity. *British Food Journal, 110,* 622-635.

Tenbült, P., De Vries, N. K., van Breukelen, G., Dreezens, E., & Martijn, C. (2008). Acceptance of genetically modified foods: The relation between technology and evaluation. *Appetite, 51*, 129-136.

Torgersen, H., Hampel, J., Bergmann-Winberg, M. L., Bridgeman, E., Durant, J., et al. (2002). Promise, problems and proxies: twenty-five years of regulation and debate in Europe. In M. W. Bauer & G. Gaskell (Eds.), *Biotechnology: The making of a global controversy* (pp. 21-94). Cambridge: Cambridge University Press.

White, M. P., Pahl, S., Buehner, M., & Haye, A. (2003). Trust in risky messages: The role of prior attitudes. *Risk Analysis, 23,* 717-726.

Wilson, C., Evans, G., Leppard, P. & Syrette, J. (2004). Reactions to genetically modified food crops and how perception of risks and benefits influences consumers' information gathering. *Risk Analysis, 24,* 1311-1321.

Wolf, D. & Vögele, G.A. (2009). Time requirements and financial expenditures for coexistence measures and their impact to profitability of genetically modified plants in Switzerland. In: Co-Extra (2009). GM and non-GM supply chains: Their co-existence and traceability. Abstracts of the Co-Extra International Conference, 2-5 June 2009, Paris, p. 146. http://www.coextra.eu

Zechendorf, B. (1994). What the public thinks about biotechnology. *Biotechnology, 12*, 870-875.

This literature review is part of the National Research Programme NRP 59 "Benefits and Risks of the Deliberate Release of Genetically Modified Plants". It is one of a total of three such reviews, which are:

- Medical issues related to genetically modified plants of relevance to Switzerland
- Genetically modified crop production: social sciences, agricultural economics, and costs and benefits of coexistence
- Synthesis and overview studies to evaluate existing research and knowledge on biological issues on GM plants of relevance to Swiss environments

They aim to distil relevant scientific data from the results of international studies on GMP that could help to shape future research and decision-making processes in Switzerland.

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