Zeitschrift: Yearbook of socioeconomics in agriculture : Agrarwirtschaft und Agrarsoziologie = économie et sociologie rurales

Herausgeber: Schweizerische Gesellschaft für Agrarwirtschaft und Agrarsoziologie

Band: - (2009)

Artikel: Economic consequences of GMO traceability in the EU food and feed industry

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DOI: https://doi.org/10.5169/seals-966648

Economic Consequences of GMO Traceability in the EU Food and Feed Industry

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The application of genetically modified organisms (GMOs) in agriculture and food production has steadily increased in the recent years, while EU consumers` acceptance of using GMOs in the food area is still very low. In order to ensure consumers` and users` freedom of choice, the EU adopted specific regulations whereby food and feed products have to be labelled if containing more than 0,9 % of GMOs. This led to an increasing need of GMO testing for the EU food and feed industry. This study aims to analyse the economic consequences of GMO traceability within this industry. Furthermore, it also investigated if the need for GMO testing created new economic and business opportunities for producers of analytical test kits as well as for diagnostic laboratories usually carrying out these tests. In summary it can be stated that the economic impact in terms of turnover, additional costs and employment is rather small for all three business sectors.

Keywords: GMO, traceability, food/feed industry

JEL Classification: L51, Q18

Marina Zapilko, Sandra Feigl, Klaus Menrad, Tobias Hirzinger: Economic Consequences of GMO Traceability in the EU Food and Feed Industry: Yearbook of Socioeconomics in Agriculture 2009, 81-112

1. Acceptance of genetic engineering in the agro-food sector and its consequences

Due to its various application possibilities genetic engineering is considered as one of the 21st century´s key technologies (Menrad et al. 2003). While its application is quite accepted e.g. in the fields of medicine and pharmacy, it is still rather critically evaluated regarding the production of food and feed. But despite this intensive public debate, the use of genetically modified organisms (GMOs) in the fields of agriculture and food production has been continuously increased since years and reached around 125 million hectares in 2006. But although voluntary testing procedures in the United States have not found food safety problems deriving from GMOs and GM materials in food products there is still a low acceptance of applying genetic engineering approaches and resulting products in the agro-food sector especially among European consumers (Hucho et al. 2005; Evenson and Santaniello 2004; Hirzinger 2008; Clive 2006; Costa-Font et al. 2008).

Conservationists disapprove genetic engineering in the agro-food sector because of biosafety considerations namely the fear of uncontrolled gene transfer and possible reduction of biodiversity. Also in the opinion of most consumers there is nothing to gain by GMO ingredients but serious disadvantages may occur. Reasons for the low acceptance among consumers are the extreme difficulties of reversing GMO technology as soon as it becomes a widespread used technology, a raising monopolisation of seed and food processing companies resulting in a larger dependence of farmers as well as ethical concerns (Frank 2004; Wisner 2002; DG AGRI 2002; Gaskell et al. 2006). Potential negative health impacts as well as potential adverse environmental effects are, however, decisive for the perception and acceptance of GM food and feed by EU[1] consumers. This relates in particular to countries with below-average support of GM food in the EU (mainly Central European countries like Germany, Austria, the Netherlands, Luxemburg, several new Member States like Hungary, Poland, Slovenia and the Baltic countries, and some Mediterranean countries like Greece and Cyprus) as well as for consumers which do not intend to buy GM food. With some differences in the EU Member States the latter group seems to represent the

[1] In this paper EU corresponds to EU25.

majority of EU consumers since - according to the most actual Eurobarometer survey - only 27 % of the EU consumers are in favour of GM food. Even in Spain, where more than 50,000 hectares of insect-tolerant Bt maize have been planted in recent years, consumer support of GM food is only seven percent points above the European average of 27 % (Gaskell et al. 2006; Clive 2006; Costa-Font et al. 2008).

Finally, it can be concluded that GM food is mainly accompanied by the perception of a relatively high risk (Gaskell et al. 2006; Costa-Font et al. 2008) which is unacceptable especially for many EU consumers. Therefore and against the background of the worldwide increasing use of genetic engineering in the agro-food sector, the EU adopted a series of regulations related to GMOs. Among them the regulations (EC) No 1829/2003 and 1830/2003 dealing with the admission, labelling and traceability of GMOs have a special impact on the food and feed industry (Jany and Schuh 2005; Hirzinger 2008). Important targets of these regulations are to ensure freedom of choice for consumers and users of GM and non-GM products as well as to avoid environmental and health risks associated with the commercial use of GM products (European Parliament and the Council of the European Union 2003a/b). However, it is important to have in mind that the aforesaid regulations deal with GM food and feed products which have been approved in the EU after intensive safety testing procedures either for commercial use, import or export. GM food and feed should only be authorised for placing on the EU market after a scientific evaluation of any risks which they present for human and animal health and for the environment (European Parliament and the Council of the European Union 2003a), i. e. GM food and feed which are approved for commercial use in the EU are regarded by the regulatory authorities to be safe for consumers and do not cause any adverse effects to the environment or ecosystems - at least at the current stage of knowledge.

In detail, according to regulations (EC) No 1829/2003 and 1830/2003 food and feed products have to be labelled to contain GMOs or GM material in case a tolerance threshold of 0,9 % is exceeded for EU authorised GMOs and 0,5 % for unauthorised GMOs if they have already received a favourable EU risk assessment. Products containing traces of GMOs below the appropriate regulatory thresholds are exempt from labelling, provided that compliant traceability systems are in place and traces of GMOs are adventitious and technically unavoidable. Also ani-

mal products which were produced with GM feed compounds have not to be labelled. Products containing GMOs above the threshold must be labelled as such, even if the GM material is undetectable by analytical tests. In these cases, product traceability has to be mandated through documentation systems and implementation of these systems for the entire supply chain (Fagan 2004; European Parliament and the Council of the European Union 2003a/b). Traceability requirements for GM food and feed and the corresponding documentation and traceability systems also should facilitate the withdrawal of products where unforeseen adverse effects on human and animal health or the environment are detected as well as the continuous monitoring in order to examine potential long-term effects on the ecosystem (European Parliament and the Council of the European Union 2003a).

Thus, the EU food and feed industry is faced by the dilemma of consumers who reject GMOs to a large extent, the legislation which contains definite instructions (in particular in the field of labelling and traceability) and a world-wide increasing cultivation of GM crops (Hirzinger 2008).

Mainly the EU labelling requirements result in an increasing need for GMO detection for the European food and feed industry. GMO testing by means of analytical procedures (see next chapter) became an appropriate and very important instrument for the food and feed industry to check the presence or absence of GMOs in food products and to ensure the correct labelling of food and feed products with respect to the threshold of GM material (DG AGRI 2002).

Although the relevance of GMO testing is largely known, there are hardly any data available regarding their economic impacts on the European food and feed industry (Hirzinger 2008). This case study (which was conducted within the framework of the Biotechnology for Europe Study[2]) tries to reduce this lack of information and aims to analyse the economic consequences of GMO traceability/GMO testing procedures in this industry. Furthermore, it also investigates if the need for GMO testing created new economic and business opportunities for producers of analytical test kits as well as for diagnostic laboratories usually carrying out these tests.

[2] See http:// bio4eu.jrc.ec.europa.eu/.

The next chapter of this paper gives a short overview over different GMO testing procedures. This is followed by a description of the study's methodology and the experimental design. The empirical results are portrayed in chapter 4, followed by main conclusions which can be drawn on the basis of these findings.

2. GMO testing procedures

In order to ensure EU consumers' freedom of choice between GM and non-GM food products, the relevant EU regulations require that food and feed products are labelled if they contain more than 0,9 % GMOs. Therefore, operational procedures for the detection, identification and quantification of GMOs in the agro-food value chain have been developed and implemented which are necessary in order to fulfil the regulatory EU requirements in this field (Pawlik 2003).

GMOs can be detected by analytical tests due to the fact that they contain unique novel proteins and/or DNA sequencies which are not inherent in the conventional products. Basically there are two methods used to identify GMOs: Enzyme Linked Immunosorbent Assay (ELISA) tests and Polymerase Chain Reaction (PCR) tests. The principles of both techniques are briefly described in the following.

The ELISA-method works on the basis of protein antibody tests which can detect and quantify the amount of specific proteins in a sample. This method works with antibodies to bind certain proteins. Antibodies are defined as proteins which are produced by the immune system when exposured to foreign substances, the so-called antigens. In the case of GMOs the antigen is the newly developed or introduced protein. By fluorometric or colorimetric reactions the interconnection of the antigen and the specific antibody can be visualised and measured. ELISA-tests require high investments for developing the assay and for generating the antibody standards. Furthermore, trained personnel and special equipment are needed. The test is reported to be 95,0 % accurate (DG AGRI 2002; Glick and Pasternak 1995; Deckwer et al. 1999). They are mainly used to help farmers and elevators to separate their GMO grain lots from non-GMO grain lots.

In contrast to ELISA-tests, the PCR method detects DNA fragments which are inherent in the genome. In a few hours specific DNA fragments are amplified to a degree that they can be analysed both qualitatively and quantitatively by means of common techniques used in laboratories (e. g. electrophoresis). The advantage of PCR tests is their high sensitivity regarding unprocessed food in which the DNA is still intact and in place. Processed food, however, can contain more than one GMO variety, which complicates the detection. Moreover, it is difficult to isolate high quality DNA in processed foodstuff. As in the case of ELISA-tests, PCR needs special equipment and trained personnel. The PCR-tests deliver in 99,9 % of all cases exact results (DG AGRI 2002; Glick and Pasternak 1995; Deckwer et al. 1999). DNA tests using PCR technology are used to make decisions concerning storage or separating grain lots, but more often they are used for breeding, production and marketing decisions involving seed, grain, food ingredients, and processed food products. DNA/PCR methods are generally considered to be the preferred method for detecting "any GMO".

According to available literature, in practice mainly ELISA- and PCR-tests are applied to qualify and quantify GMOs and GM material in food and feed. Furthermore, there are no applicable tests on the market using alternative conventional methods (e. g. chromatography, NIR, SMD) (Bonfini et al. 2001). Therefore, this case study concentrates on these two methods.

3. Materials and methods

3.1 Rationale of the case study

As already described in chapter 1 the main objective of this case study within the Biotechnology for Europe Study is to quantify the economic impact of GMO testing on the food and feed industry.

Although the issue of GMO traceability affects the whole agro-food sector the value chain levels of agriculture, food retailer and private food consumption are excluded from the analysis. The predominantly negative perceptions of consumers towards GM food had direct conse-

quences on the strategy of retailers. Being confronted with an increasing public pressure to phase out GM products, many retailers adopted a restrictive position towards GM food and require from the food industry own-brands which are GM free or products being labeled according to the EU legislation (Strecker et al. 1996; DG AGRI 2002). For the food industry system failures are penalized by retailers with exclusion from the listing up to criminal prosecution and are always combined with a high loss of profit, consumer trust and reliability (Smith and Phillips 2002). Costs of GMO traceability and of GMO testing therefore mainly incur at the primary production sector and the food and feed industry. While the economic consequences resulting for the agricultural sector from regulations dealing with genetic engineering are well investigated (e.g. EU financed projects CO-EXTRA[3] and SIGMEA[4]), such analysis is largely missing for the food and feed industry (Hirzinger 2008). This study aims to analyse the economic consequences of GMO-related traceability testing procedures in the European food and feed industry. Furthermore, it analyses if and how the increasing need for GMO testing affects other industry sectors as e.g. producers of analytical test kits and diagnostic laboratories usually carrying out these tests.

3.2 Empirical approach

3.2.1 Test kit producers and diagnostic laboratories

The consequences and opportunities of the traceability system of GMOs on test kit producers and diagnostic laboratories have been analysed within this case study using specific indicators. These indicators (see Table 1), which were developed within another task of the Biotechnology for Europe Study (Reiß et al. 2006), cover the company level and deal with the impact which GMO testing has on companies` turnover and employment. In order to get more insight in this specific market additional questions were asked concerning the structure of costs and prices as well as the advantages and disadvantages which an increasing need for GMO testing may have for the corresponding company.

[3] CO-EXTRA: Co-existence and traceability of GMO ingredients along the food chain
[4] SIGMEA: Sustainable introduction of GMOs in to agriculture

Finally, the interviewees should assess the future market development regarding GMO testing.

Tab. 1: Elaborated indicators for test kit producers and diagnostic laboratories

Phenomenon	**Indicator**
Impact of GMO testing on **turnover** of companies	Share of GMO testing turnover out of total turnover for firms producing test kits / carrying out analytical tests for identification of GMOs in food and feed
Impact of GM testing on **employment** of companies	Share of employees active in GMO testing in firms producing test kits / carrying out analytical tests for identifying GMOs in food and feed out of total employment
	Share of jobs created through production of test kits / carrying out analytical tests for GMO identification related to all jobs created by these firms

Source: Reiß et al. 2006.

Due to the short duration of the study (six months) as well as budgetary constraints it was not possible to carry out face-to-face interviews. Therefore, in June 2006 11 phone interviews were conducted with representatives of different small and medium sized companies (five test kit producers and six diagnostic laboratories) active in the EU. In order to guarantee a consistent approach towards the complex issue of GMO the interviews were guideline-based and carried out by the same interviewer. The interviewees were located in Austria, Germany, Hungary, the Netherlands, Poland and the United Kingdom. Further contacted companies in Spain, Portugal and France could not be interviewed due to schedule difficulties of the contacted persons or due to confidentiality reasons. That means that with Germany only one of the European grower countries of GM crops is represented in the sample (Clive 2006). However, in the opinion of the authors this fact does not derogate the quality of the study and its results as also the food industry in countries not growing GM crops can be affected by the GMO issue due to imports

of GM raw materials or the use of genetic engineering in the food production processes (e.g. GM additives, GM enzymes) (Hirzinger 2008).

A slightly larger difficulty results from the fact that it is not possible to classify the interviewed companies against the background of the entity of firms being active in GMO testing in the EU, as the universe of these companies is unknown so far[5]. But again, also these circumstances do not influence the study´s quality a lot.

3.2.2 Food and feed industry

Also companies of the European food and feed industry should be interviewed in order to get information on the economic impact of GMO testing. However, it was hardly possible to collect data from single companies as they refused to participate in the study mainly due to the confidentiality character of the requested data as well as a general hesitation to give interviews in the sensitive field of GMO application in foods. Therefore, six big associations of the German bakery, milling, dairy and confectionary industries were interviewed (following the same approach as described in chapter 3.2.1) and asked for a general assessment of the situation.

Furthermore, additional data were available resulting from a survey undertaken by the University of Applied Sciences Weihenstephan in Germany. In May 2005 a comprehensive written survey was carried out in Germany with a total of 1700 questionnaires mailed to food and feed processing companies in order to investigate and analyse the effects of regulations (EC) No 1829/2003 and 1830/2003 on the German food and feed industry. The response rate to this survey was around 20 % (Hirzinger and Menrad 2006). Table 2 gives an overview (in terms of total number of companies active in Germany, sent questionnaires, response rates and examples of used GM ingredients) of those five branches of the food and feed industry which were separately analysed for this case study as key branches being affected by the application of GMOs. Thus, the empirical basis for the specific results created within this case study are filled in questionnaires of 32 bakery companies, 4 oil mills, 29 dairy

[5] Some information concerning official laboratories carrying out GMO tests can be derived from the European Network of GMO Laboratories (ENGL) (http://engl.jrc.ec.europa.eu/), but this network does not comprise commercial test kit producers.

companies, 27 confectioneries and 40 feed producers located in Germany.

Tab. 2: Affected food and feed processing industries and corresponding GM ingredients

Food/feed industry branches	Number of companies active in Germany (2003)	Sent questionnaires	Response rate	Examples for GM ingredients
Bakery industry	138	134	32 (23 %)	Amylase or other enzymes
Oil mills	34	26	4 (15 %)	Raw materials (e. g. oilseed rape), enzymes
Dairy industry	261	127	29 (23 %)	Chymosin
Confectionary industry	158	147	27 (18 %)	Lecithin (derived from soybeans), Isoglucose (derived from maize)
Feed industry	217	137	40 (29 %)	Soybeans (N-, HP-extraction shred; soypods)

Source: Hirzinger, 2008

4. Economic impacts of GMO traceability

4.1 Producer of test kits for the identification of GMOs

As already described at present mainly ELISA- and PCR-tests are used for the identification of GMOs. Companies which produce analytical test kits for the identification of GMOs in food and feed predominantly manufacture PCR-tests while ELISA-tests are produced only to a small amount (four of the five interviewed test kit producers only produce PCR-tests). This is mainly due to the fact that PCR-tests show a much better accuracy for quantitative analyses compared to ELISA-tests, which are mainly used for qualitative analyses. Food processing companies which test their ingredients and products on GMOs, however,

particularly require quantitative test methods in order to check if the ingredients exceed the current threshold of 0,9 % GMO content in order to comply with the EU´s labelling requirements. In this sense the producers of analytical test kits adapt their business activities to the food and feed companies` demands.

In general, the interviewed companies gave only very few information concerning the turnover as these details underlie strict confidentiality. This applies both to the total turnover and to the turnover which is realised by the production of analytical test kits for the identification of GMOs. Therefore, only few data could be elicit, which hardly permit to make an exact evaluation of the situation. Since companies of different size (e. g. measured in total turnover or number of employees) were interviewed the total annual turnover ranges between 300 000 € and 6 million € per year. The share of the turnover which is realised due to the production of analytical test kits for the identification of GMOs in food and feed is rather small and ranges between 9 % and 13 % of the total annual turnover of the interviewed companies (see Table 3).

Exact numbers concerning the costs which incur due to the production of analytical test kits for the identification of GMOs in food and feed could not be elicit. However, the interviewees provided some information whether and to what extent the costs for the production of analytical test kits for the identification of GMOs differ from the production costs of analytical test kits which are used e. g. for detection of micro-organisms. According to the information given by the interviewees, there are actually no differences regarding the costs of production per se between the different purposes of the test use. However, for each GMO variety a specific new test must be developed. Furthermore, these tests are subject to constant changes due to changing standardisations. Due to these permanent standardisation requirements additional expenses result for producing GMO tests compared to tests which are not used for the identification of GMOs.

Due to the low generated turnover, the production of analytical test kits for the identification of GMOs in food and feed is not a very promising business field for many of the interviewed companies. According to information given by the interviewees, it would not be profitable for most of the interviewed firms only to produce test kits for GMO identification. Mainly, they also produce other analytical test kits for different purposes

and offer apart from selling the test kits also service activities like e. g. carrying out of the analytical tests.

The prices of the test kits for the identification of GMOs in food or feed can not be indicated in general. On the one hand they depend on the kind of the applied test (qualitative or quantitative) and on the other hand on the required specificity of the test. Normally the price for one test kit for a qualitative analysis of GMO is about 6 €, the price for one test kit for a quantitative analysis of GMO is about 10 €. But the interviewees emphasised as well that test kits which fulfil a high specificity cost up to 46 € per test (see Table 3).

Altogether the interviewed companies employ between 4 and 500 employees. In one firm the share of employees working in the development, production and marketing of analytical test kits for the identification of GMOs is 50 %. But this situation is rather exceptional, since the proportion of employees dealing with GMO test kits ranges from 1 % to 22 % in the other interviewed companies (see Table 3). Therefore, it can be concluded that there is no huge impact on the general employment level and structure of the interviewed companies due to the development, production and marketing of test kits for GMO identification.

If changes regarding the employment situation in the recent five years are analysed it is noticeable that only few companies created new jobs in general. Many firms have rather cut jobs during this time period, which is most likely connected to the present tough economic situation in the EU in general and related to the biotechnology industry in particular (e. g. due to financing constraints). In addition, many smaller test kit manufacturers were acquired or merged with larger companies. Only in one case new jobs have been created, of which 17 % account for employees who are engaged in development, production and marketing of test kits for the identification of GMOs in food and feed (see Table 3). This fact again indicates the very limited impact of this business field on the employment level and structure of the test producing and analytical industry in the EU.

Tab. 3: Overview elaborated indicators (test kit producers)

Phenomenon	Indicator	Values margin
Impact of biotechnology on **turnover**	Share of biotechnology turnover out of total turnover for firms producing test kits for identifying GMOs in food and feed	9-13 %
Impact of biotechnology on **employment**	Share of biotechnology active employees in firms producing test kits for identifying GMOs in food and feed out of total employment	1-50 %
	Share of jobs created through production of test kits for GMO identification related to all jobs created by the firms producing test kits for identifying GMOs in food and feed	17 % in one company Remaining companies have not created new jobs.
Production costs	Total production costs of test kits for the identification of GMOs in food and feed	Only qualitative data available
Prices	Prices of test kits for the identification of GMOs in food and feed	6-46 €/test kit

Source: Own depiction

According to the interviewed companies the production of test kits for the identification of GMOs has no huge influence regarding qualification requirements towards the employees, as the production procedures of GMO test kits differ only minimally from non-GMO test kits. In case additional know-how is required for employees, this can be applied by further education of employees. One of the interviewed companies, however, stated that per firm about one to two more molecular biologists are needed for the advancement of the tests what might rise the demand for molecular biologists slightly. Besides, the emerging of the business field of GMO test kits had not led to an increased demand for academics or PhD-graduates. But this can also be explained by the fact that companies developing and producing analytical test kits are already highly "knowledge based" what is underlined by the fact that they generally have a very high number and proportion of academics and employees with a PhD of different scientific disciplines.

As already stated many test kit producers also offer service activities like e. g. to carry out the analytical test procedures to identify GMOs in food and feed. These companies see an advantage in manufacturing analytical test kits for GMO detection as well as offering services in order to benefit from the subsequent step of the value chain. Furthermore, the market for the GMO test kits is classified by the interviewed companies rather as a small market. They estimated that only 15 to 20 % of all test kit producers in Germany manufacture GMO test kits. Data for the EU could not be elicit. According to the interviewed companies firms which produce test kits for the identification of GMOs are not yet exposed to a large competitive situation.

The interviewed companies indicated the additional costs of producing analytical test kits for the identification of GMOs as a clear disadvantage. As previously mentioned these costs result particularly from the need to advance the test kits (due to new GMO varieties) and to adjust them to certain standards. According to the interviewees it is hard for private suppliers of GMO test kits to prevail against national laboratories. For them it is possible to work always with the best standardised methods as national laboratories are assisted by financial means of public authorities. Customers, however, demand for these high standards which are often set by national laboratories. Therefore, private suppliers need to invest in expensive equipment and methods.

Especially the regulatory framework of GMOs in the EU had and still has high influence on the developments in the test kit producing companies. The leave-taking of the regulations (EC) No 1829/2003 and 1830/2003 resulted in a strict labelling requirement of food and feed containing more than 0,9 % GMOs or GM-derived material. Therefore, an increasing number of companies of the European food and feed industry test their ingredients or rather processed products than it was the case before the leave-taking of these regulations in 2004. In this sense the demand for test kits for the identification of GMOs has increased in the recent years but the interviewed company representatives were not able to exactly estimate growth rates or the demand level for EU.

The market developments related to GMO detection in the coming years will be noticeably dependent on the regulatory framework in the EU. The interviewed company representatives expected that an increasing number of GMOs will be approved in the EU, for which new specific tests

must be developed. This will have an impact on costs, turnover as well as on the number and qualification of the employees, but the interviewed company representatives were not able to quantify these impacts. The development of new tests for newly approved GMOs and their standardisation will slightly increase the total costs of the companies. However, as the demand for test kits for the identification of GMOs will presumably increase as well the higher costs might be overcompensated by the growth in turnover thus leading to decreasing costs per unit due to economies of scale. In addition, the interviewed companies expected that they will create a limited number of new jobs in the future due to added production of test kits in particular for molecular biologists.

According to the interview partners the procedures and methods for the identification of GMOs will not noticeably change in the near future. They are convinced that mainly PCR-tests will be produced in the coming years as well. Furthermore, the tests will have to be more and more standardised and harmonised which will result in additional costs for the test kit producers.

4.2 Diagnostic laboratories

The total annual turnover of the interviewed diagnostic laboratories which carry out analytical tests to identify GMOs in food and feed ranges between 150 000 € and 18 million € per year. The proportion of the total turnover which is realised with GMO testing of food and feed ranges between 0,06 and 50 % in the interviewed companies (see Table 4). A share of 50 % on the total turnover, however, is the very exception and occurred only in one company. Considering the proportion in the other companies, most diagnostic laboratories realise less than 1 % of the total turnover by carrying out analytical tests for the identification of GMOs in food and feed. This indicates on the one hand that this part of the analytical market is a small market despite the existing traceability and labelling rules in the EU and on the other hand that GMO testing is mostly a supporting business used to win and bind customers.

For the laboratory companies costs between 40 000 € and 50 000 € per year incur due to the carrying out of analytical tests on GMOs in food and feed (see Table 4). According to the information given by the interviewees, the costs of GMO identification analyses are comparable to

those of other analytical analyses. However, especially analyses for the identification of GMOs require relatively high investment costs as a special and expensive laboratory equipment is needed. Therefore, for many diagnostic laboratories it is actually not profitable to accomplish analyses for the identification of GMOs as the realised turnover is rather small compared to the incurring costs. For these companies offering of GMO analyses has rather a strategic reason (i. e. binding of customers of the food industry) than a directly economic one: They want to supply a full-service package to their customers who should be able to have been made all relevant analyses by one firm (i. e. in the sense of "one-stop-shopping"). Thereby the diagnostic laboratories try to prevent that their food industry customers turn to a competing laboratory company.

Similarly to the prices of the test kits the prices for the carrying out an analytical test to identify GMOs in food and feed can not be indicated in general. They depend on the kind of test which should be carried out. Screening tests which are used for the qualitative detection of GMOs cost between 100 € and 120 €/test. Analytical tests which quantitatively determine the content of GMOs in certain products usually cost between 130 € and 570 €/test (see Table 4). In this case the price depends on whether raw material or highly processed food products have to be analysed. In the latter case it is more difficult to accomplish an analytical test which leads to higher prices for the test procedure. Furthermore, the price for a quantitative test also varies corresponding to the fact if already a qualitative test was carried out or not. If the sample has not been screened (qualitative test) before, the price increases. The carrying out of very specific tests which show very accurate results can cost up to 2000 €/test.

In total the interviewed diagnostic laboratories employ between 5 and 1200 employees per company. It was hardly possible to elicit the share of employees who accomplish analyses for the identification of GMOs in food and feed. This is due to the fact that in many of these companies the employees do not solely carry out GMO analyses but also any other analytical test. Therefore, a differentiation of employees with respect to the character of the tests they are carrying out is almost impossible. In those companies which tried an estimation the share of employees carrying out GMO tests it ranges between 0,75 % and 40 % (see Table 4). Due to above mentioned difficulties these data have to be interpreted extremely cautiously.

Concerning possible changes in the employment situation there is no statement possible as actually none of the interviewed companies (with one exception) has created any new jobs within the recent years. One of the firms was founded in 2001 and has therefore employed 15 persons. 40 % of them accomplish analyses for the identification of GMOs (see Table 4).

Tab. 4: Overview elaborated indicators (diagnostic laboratories)

Phenomenon	Indicator	Values margin
Impact of biotechnology on **turnover**	Share of biotechnology turnover out of total turnover for firms carrying out analytical tests for identification of GMOs in food and feed	0,06-50 %
Impact of biotechnology on **employment**	Share of biotechnology active employees in firms carrying out tests for identification of GMOs in food and feed	0,75-40 %
	Share of jobs created through carrying out tests for GMO identification related to all jobs created by the firms carrying out tests for identification of GMOs in food and feed	40 % in one company. Remaining companies have not created new jobs.
Costs of carrying out analytical GMO tests	Total costs of the carrying out of analytical GMO tests	40 000-50 000 €/year
Prices	Prices of GMO tests	100-570 €/test

Source: Own depiction

According to the interviewed laboratory companies the carrying out of analytical test procedures for the identification of GMOs in food and feed does not have special impact on the required qualification of employees. There is no added demand for academics or PhD graduates as the analyses of GMOs hardly differ from any other analytical analysis. In case additional know-how is required this can be obtained by further education of employees. In most cases even an instruction of the employees by an expert is sufficient. However, some companies indicated that it is important for them to employ experienced personnel for the GMO analyses. As the analytical methods for GMO identification are standardised an exact and structured work is necessary. In addition,

many diagnostic laboratories developed a quality management system which must be documented exactly. Also for this task reliable and precisely working employees are needed.

In Germany 15 to 20 % of all diagnostic laboratories carry out GMO tests. In the EU there are about 50 diagnostic laboratories which accomplish GMO analyses. Most of them are located in France, Germany and Austria.

The interviewed laboratory companies see particularly the special "customer care" as main reason for carrying out GMO analyses in food and feed. Thus, they can offer a full-service-package to their clients in the food industry and therefore many of the interviewed companies regarded the supply of GMO analyses as a mean of customer binding. Mentioned disadvantages are the relatively high investment costs and the additional expenditures which incur due to the GMO analyses. Additional expenditures result especially from quality management systems which many companies have realised since they are carrying out GMO analyses for the food and feed industry.

The influential factors for laboratory companies which carry out analytical tests for the identification of GMOs are very similar to those mentioned by the producers of test kits. According to the interviewees the recent developments were mainly influenced by the regulatory framework. Due to the requirements of the EU regulations (EC) No. 1829/2003 and 1830/2003 several food and feed industry companies assign external laboratories with analytical tests for the identification of GMOs. Therefore, the demand for analytical tests in diagnostic laboratories slightly increased in this field.

According to the estimation of the interviewed representatives of laboratory companies, the development in the coming years will mainly depend on political decisions and the regulatory framework relevant for GMOs in the EU. Due to the increase of GM approved varieties the demand for analytical test procedures will presumably rise in the coming years. At present many companies of the EU food and feed industry comply with the EU labelling regulations primarily by demanding special certifications by their suppliers. It is expected that if co-existence of GMO and non-GMO food is realised in the EU, also the demand for analytical tests for the identification of GMOs will increase since food and feed companies want to ensure that their products do not contain

more than 0,9 % GMOs by carrying out these tests. Due to the increased demand for analytical GMO tests the turnover which is realised by these tests will rise most probably as well as the corresponding total costs since more samples have to be tested. The average costs per unit (i. e. test on GMOs), however, will decrease due to added amount of accomplished tests and economies of scale. The interviewed experts could not give a clear estimation whether some new jobs will be created in diagnostic laboratories due to the increased demand for GMO analyses in the coming years.

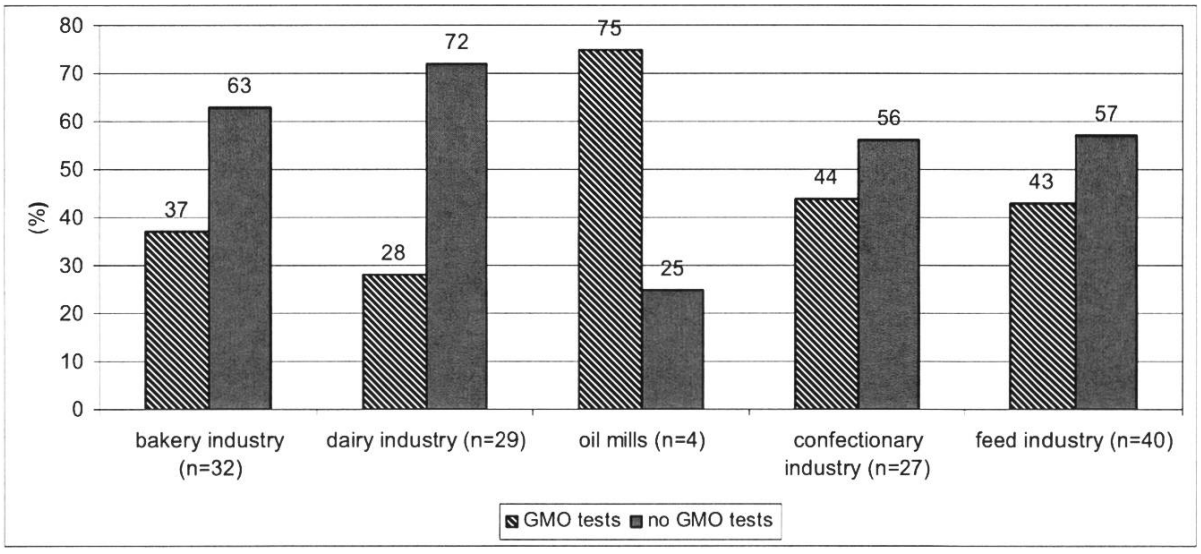
Some of the interviewees expressed the following vision of the development in around 10 to 15 years: As soon as GM products are approved which have a direct utility and advantage for European consumers (e. g. allergen-free ingredients or food products), the EU consumers´ acceptance towards GMOs will increase. If this happens the legal regulations in the EU will be perhaps loosened, which could lead again to a reduction of the "analytical boom".

4.3 Branches of the European food and feed industry

As already described it was hardly possible to elicit any data from companies active in the European food and feed industry on the economic impact of GMO testing. The contacted firms of the bakery, dairy, milling and confectionary industry were either not willing to participate in an interview or they gave only very limited information. Therefore, it was tried to get information contacting the corresponding associations. In addition, data were available from a survey among German food and feed processing companies carried out in spring 2005. The following information are based on the interviews with representatives of the food industry associations as well as on the results of this survey.

The question how many companies test their ingredients or processed food products on GMOs must be considered with respect to the different industry branches. In Germany the majority of the oil mills (75 %) carry out analytical tests for the identification of GMOs. This high proportion can be explained by the fact that in the oil processing industry raw materials (like e. g. soybeans, oilseed rape) are predominantly used for which approved GMOs exist for the EU as well as the high adoption rates of GM varieties in major producing countries (such as USA, Argen-

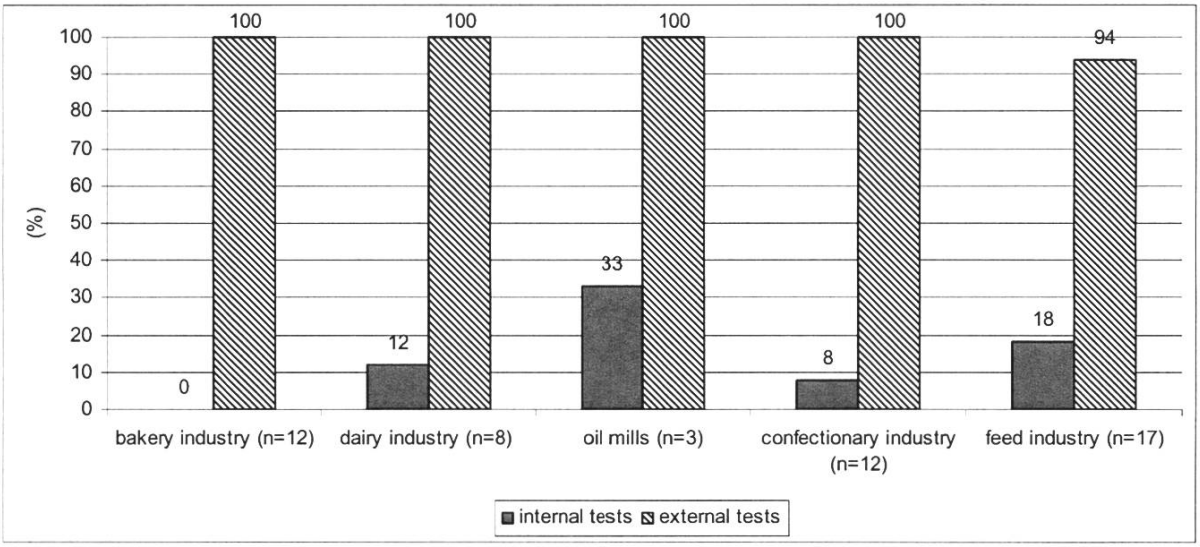
tina and Brazil for soybeans and Canada for oilseed rape). As in particular in the case of soybeans raw materials are imported from these countries, there is a high risk that these raw materials might contain GMOs. In contrary, the situation in the German dairy industry turns out to be different: Only a limited part of the companies carries out analytical tests for the identification of GMOs (28 %) (see Figure 1). At present in most companies of this industry branch only GM ingredients are utilised which have not to be labelled (e. g. enzymes) or which can not be detected any more by analytical tests in the final food product sold to consumers. Some companies of the milk industry, however, test their ingredients which are added to specific milk products, e. g. chocolate. In the case of the bakery, confectionary and feed industry in Germany a higher proportion of the companies test their products (37 %, 44 % and 43 % respectively) concerning GMO content (see Figure 1). This can be explained by the fact that some key food/feed ingredients are used in these branches (like e. g. lecithin, isoglucose) which derive from raw materials with a significant part of production of GM varieties on a worldwide level which are also imported to the EU.



Source: Survey of University of Applied Sciences Weihenstephan, 2005.

Fig. 1: Proportion of companies carrying out analytical GMO tests in different food and feed industry branches in Germany.

As shown in Figure 2 only a (very) limited part of the German food and feed industry companies actually conducting GMO tests carries them out in in-house laboratories. Most firms assign external diagnostic laboratories with these analyses (94 % to 100 % of the responding industries). Particularly, smaller companies of the food and feed industry do not have the required laboratories, equipment and/or know-how to test their food/feed products for their GMO contents and thus assign external labs with these analyses. This behaviour of food/feed industry companies seem to be similar in other EU Member States according to information given during the interviews.

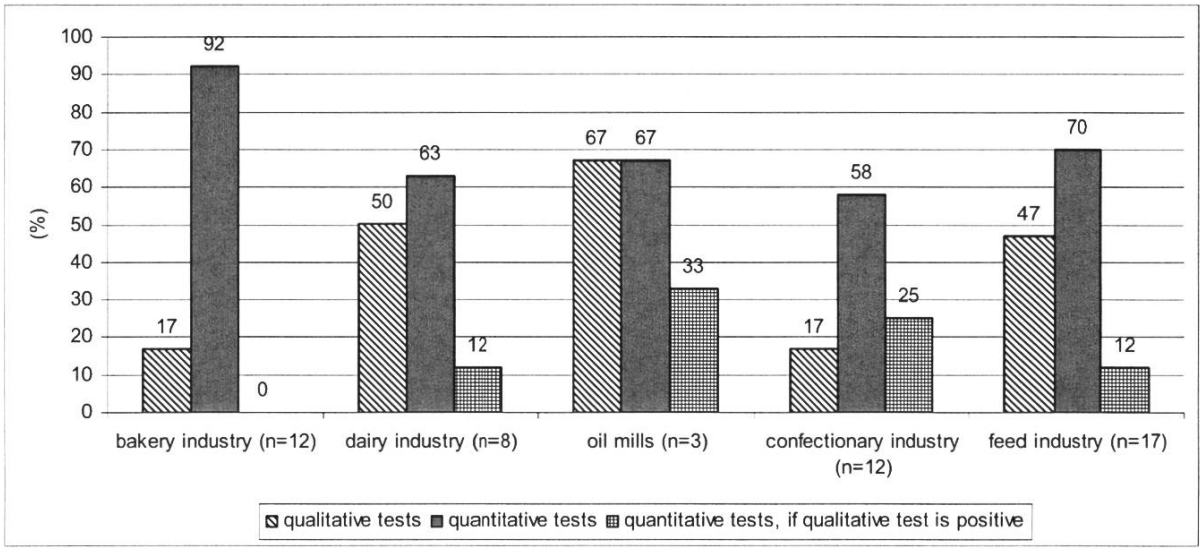


Source: Survey of University of Applied Sciences Weihenstephan, 2005

Fig. 2: Proportion of German food and feed industry companies carrying out GMO tests internally and externally.

As already described the GMO content of food and feed products can be quantitatively analysed or so-called screening tests are carried out which only analyse the samples in a qualitative manner. Only 17 % of the bakery companies and 17 % of the confectionary firms which carry out GMO tests accomplish such qualitative tests in Germany. However, the proportion among the oil mills and the feed industry is 50 % and 47 % respectively (see Figure 3) which might be due to the high quantities of raw materials imported from Latin and North America which are processed in these industries. A significant part of the food and feed

industry companies of the relevant branches carries out quantitative GMO tests. For these companies it is not only important to know if their ingredients and products contain GMOs or not, but also to what extent, as this value is decisive regarding the labelling requirements of the EU. Therefore, a quantitative analysis is more appropriate for most companies than a qualitative test. Also the prices for quantitative tests are only slightly higher than for qualitative tests. Some companies, however, carry out first a qualitative analysis. If the result is positive, then they apply a quantitative test (see Figure 3).



Source: Survey of University of Applied Sciences Weihenstephan, 2005

Fig. 3: Proportion of food and feed industry companies in Germany carrying out qualitative and quantitative GMO tests respectively.

The question arises if the labelling requirements and therefore the need of GMO analyses have induced a noticeable change in the employment structure of the companies of the food and feed industry. For carrying out GMO tests no additional employees are necessary in most companies as they mainly assign external laboratories with these analyses. In many firms the traceability of their products is ensured by written documentation required by their suppliers. This leads to an additional administrative effort. Also the realisation of a corresponding quality management system increases the amount of work. Both have encouraged some firms to employ new staff members. However, in most companies

these additional tasks are managed by already existing personnel. The corresponding job creation is therefore rather small. Also the requirements on the employees´ qualification have not changed considerably.

The costs of additional GMO testing in the food and feed industry were analysed in the survey among German food and feed processing companies as well. These are predominantly costs for GMO analyses, higher costs of changing the raw material basis or buying raw materials from other regions as well as for additional personnel requirements. Table 5 provides an overview of the occurrence of these costs in German food and feed companies in 2005. Additional personnel costs throughout regulations (EC) No 1829/2003 and 1830/2003 mentioned 33,0 % of all participating food and feed producers of this survey. Additional costs for GMO free raw materials are relevant for 35,2 % of the food and feed producers, while around 40,2 % of the food and feed producers reported additional costs due to GMO analyses.

Tab. 5: Occurrence of additional costs of traceability and labelling requirements of GMOs in selected branches of the German food and feed industry 2005 (% of all responding companies)

	Analytical testing of GM content of products	Higher costs of raw materials	Additional personal costs
Bakery industry (n=32)	36	23	29
Dairy industry (n=29)	28	17	38
Oil mills (n=4)	50	75	25
Confectionary industry (n=27)	44	26	30
Feed industry (n=40)	43	35	43
Total	**40,2**	**35,2**	**33,0**

Source: Hirzinger and Menrad, 2005

A crucial question is the level of the cost effects which are caused by GMO testing in food and feed industry companies. The survey among German food and feed processing companies tackled this question. An overview of the costs of GMO testing regimes in different branches of the German food and feed industry is given in Table 6. When interpret-

ing this data the limited number of answers should be taken into account, but nevertheless it gives insight in the testing behaviour and the cost level of GMO testing regimes. While there are only rather small differences in the average costs of single tests (both for qualitative and quantitative GMO testing), the number of tests carried out by the different branches differ significantly between the milling, confectionary dairy and feed industry on the one hand and the bakery industry on the other hand in case of quantitative tests and between the dairy and confectionary industry on the one hand and the feed industry on the other hand in case of qualitative tests (see Table 6). Although the total average costs of GMO testing also differ strongly between the branches (with around 1200 €/year in the bakery industry and 14 600 €/year in the feed industry), these differences are widely smoothened when setting these costs in relation to the turnover of the companies. In addition, this table being the highest with 0,02 % in the milling industry shows that the direct costs of GMO testing are rather limited so far in the German food and feed industry - not least due to the limited number of approved GM varieties in the EU. However, it should be considered that higher costs of raw materials, additional personnel costs or costs for changing the organisation or the processing regime in a factory are not included in the costs shown in Table 6.

Tab. 6: Costs of GMO testing regimes in different branches of the German food and feed industry

	Bakery	Dairy	Milling	Confectionary	Feed
Number of quantitative GMO tests per year and company	6	28	61	44	17
Average costs of one quantitative GMO test	207 €	169 €	179 €	155 €	176 €
Number of qualitative GMO tests per year and company		26		13	80
Average costs of one qualitative GMO test		157 €		163 €	145 €
Total costs of GMO testing per year and company	1224 €	8814 €	10 919 €	8939 €	14 592 €
Costs in % of company turnover	0,01 %	0,002 %	0,02 %	0,01 %	0,011 %

Source: Survey of University of Applied Sciences Weihenstephan, 2005

The interviewed experts of the food industry associations expected that continuously more GMO varieties will be approved in the EU in the coming years which will have to be analysed by the food industry companies in the EU in order to meet the labelling requirements. Therefore, the firms expect that the costs for analyses will increase in the next years - a view that was shared by the interviewed experts of the test producing and diagnostics laboratories as well.

5. Conclusion and outlook

The application of genetically modified organisms (GMOs) in agriculture and food production has steadily increased in the recent years in many overseas countries, while EU consumers` acceptance of using GMOs in the food area is still very low. In order to ensure consumers` and users` freedom of choice, the EU adopted specific regulations (in particular regulations (EC) No 1829/2003 and (EC) No 1830/2003) which regulate the admission, labelling and traceability of GMOs in food and feed. Accordingly, food and feed products have to be labelled if containing more than a defined proportion of GMOs. This threshold has been set to 0,9 % adventitious presence of GMOs in the final food product if the GMO is approved in the EU (Jany and Schuh 2005; Gaskell et al. 2006; European Parliament and the Council of the European Union 2003 a/b; Clive 2006).

For the EU food and feed industry the compulsory labelling requirements result in an increasing significance of GMO detection. GMO testing by means of analytical procedures (ELISA- and PCR-tests) became an appropriate and important instrument for the food and feed industry to check the presence or absence of GMOs in food products and to ensure a correct labelling of food and feed products regarding the statutory tolerance levels (DG AGRI 2002; Deckwer et al. 1999).

Although thus, GMO testing gains more and more importance for the European food and feed industry, data on its economic impact on the agro-food sector are largely missing at this stage. Therefore, this case study (which was conducted within the framework of the Biotechnology for Europe Study) tries to reduce this lack of information by qualitatively analysing the economic consequences of GMO-related traceability test-

ing procedures within the EU food and feed industry. Furthermore, it also investigated if the need for GMO testing created new economic and business opportunities for producers of analytical test kits as well as for diagnostic laboratories usually carrying out these tests.

The case study is mainly based on the information given by some small and medium-sized European companies which are involved in and affected by GMO identification. In 2006 phone interviews were conducted with 17 experts from six European countries. Contacted firms included representatives of producers of analytical test kits, diagnostic laboratories which carry out these tests and associations of specific branches of the food and feed industry which are supposed to use GM ingredients (namely the bakery, oil mill, dairy, confectionary and feed industry). However, as the associations were not able to indicate exact numbers in terms of economic impacts on the corresponding branches results of a survey carried out in May 2005 among German food and feed processing companies were used additionally in order to partly fill this data gap.

Data on the total turnover and on the proportion of the turnover realised by producing and carrying out analytical tests for the identification of GMOs in food and feed on EU level were hardly to elicit since the interviewed experts lack the overview of EU. The gathered information, however, indicate that the turnover share due to GMO detection in food and feed is rather limited, ranging between 9 % and 13 % in the case of test kit producing firms and between 0,06 % and 50 % (one interviewed company) in the case of diagnostic laboratories. When interpreting these percentages the total turnover of the interviewed companies should be taken into consideration which was in all cases below 18 million € per year.

For test kit producing firms as well as for diagnostic laboratories quite high costs incur by GMO identification due to the need of a continuously advancement and standardisation of the tests and due to a specific and expensive laboratory equipment. Therefore, for most interviewed companies the production of test kits of GMOs for food and feed and the carrying out of these tests are not yet profitable and are mainly regarded as a customer loyalty and binding tool.

Most of the interviewed test kit producing firms and diagnostic laboratories have not created many new jobs in recent years and if so the new jobs are mainly not due to business activities related to GMO analyses

in food and feed. The proportion of employees dealing with the development, production and marketing of GMO test kits ranges between 1 % and 22 % in test producing companies. Again, when interpreting these percentages the total number of employees of the interviewed companies should be considered which was in all cases below 500 employees. Furthermore, there is no specific additional qualification the employees needed due to the production of GMO tests. For diagnostic laboratories it is difficult to determine the share of employees carrying out GMO tests in food and feed because most employees also accomplish any other analytical test. Also in diagnostic laboratories there is no additional demand for academics or PhD graduates due to GMO testing in food and feed.

In summary it can be stated that the economic impact of the increasing need of GMO testing in the European food and feed industry is rather small both for companies producing analytical test kits for the identification of GMOs in food and feed and for the diagnostic laboratories which carry out these tests. In almost all cases of the interviewed firms the additional realised turnover is limited and often neutralised by the comparable high costs. Furthermore, the creation of new jobs due to the identification of GMOs in food and feed is not noticeable in most companies. Also qualification requirements on the employees dealing with this task have not significantly increased.

Among the interviewed and surveyed companies and associations of the European food and feed industry mainly oil mills carry out analytical tests for the identification of GMOs followed by confectionary, feed, bakery and dairy industry. A very limited part of the firms carries out GMO tests in their own laboratories. Mainly, external diagnostic labs are assigned. In most cases food and feed industry companies realise quantitative tests as this kind of analysis is more appropriate for them considering that the GMO content is the most interesting value for them in order to fulfil the EU´s labelling requirements. The additional direct costs of GMO testing regimes are rather marginal, being in the range of 0,02 % of the total turnover or lower. However, additional costs occur in food and feed industry companies like costs of changing to GMO-free raw materials, additional personnel costs, costs of changing organisational or processing steps as well as increased liability or security assurance schemes which could not be quantified within the scope of this

case study. Also in the food and feed industry the identification of GMOs by analytical means has not led to a noticeable creation of new jobs.

Especially political decisions and the regulatory framework had and have influence on the developments in the different branches involved in and affected by GMO analytical identification in food and feed. The EU legislation on GMOs will also in the future remain the most decisive influential factor. Therefore, an assessment of future developments is only possible considering that the regulations will not change noticeably. Presumably more and more GMOs will be approved in the next years in the EU, for which new specific tests have to be developed. Furthermore, more tests will have to be carried out leading to higher costs for the food and feed industry. For test kit producers and diagnostic laboratories this will increase the costs as well as the turnover. Additionally, the experts expect that some new jobs will be created due to the risen demand for GMO identification tests. In the case of test kit producers also an increased demand for higher skilled personnel is possible which is required by the advancement of test kits.

As there is some evidence suggesting that when consumers are provided with information detailing a positive benefit of a GM food product, such as an environmental or health benefit, they partly modify their valuation of non-GM foods relative to GM foods (House et al. 2004; Lusk et al. 2004; Koivisto and Magnussion 2003; Boccaletti and Moro 2000; Vilella-Vila et al. 2005), it is interesting for future research to analyse if such beneficial GM food products will lead to a loosening of legal regulations and therefore to a reduction of GMO testing.

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