March 2014 TC-LLP/2014/3

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联合国粮食及农业组织
Food and Agriculture Organization of the United Nations
Organisation des Nations Unies pour l'alimentation et l'agriculture
Продовольственная и сельскохозяйственная организация Объединенных Наций
Organización de las Naciones Unidas para la Alimentación y la Agricultura
منظمة الأغذية والزراعة للأمم المتحدة

TECHNICAL CONSULTATION ON LOW LEVELS OF GENETICALLY MODIFIED (GM) CROPS IN INTERNATIONAL FOOD AND FEED TRADE

Rome, Italy, 20 - 21 March 2014
Technical Background Paper 2
Low levels of GM crops in international food and feed trade: FAO international survey and economic analysis

MJ631

Low Levels of Genetically Modified Crops in International Food and Feed Trade: FAO International Survey and Economic Analysis

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Acknowledgements

This document was prepared by Cemal Atici of the Trade and Market Division of FAO. Oversight and support were provided by several FAO colleagues, namely David Hallam, Jamie Morrison, Renata Clarke and Steve Crossley. Masami Takeuchi administered the survey and provided a comprehensive review of the paper. More detailed information about the study can be found in the primary paper (http://www.fao.org/economic/est/publications/en/).

Note

The country-specific information and data provided in the paper are based on the responses submitted through the FAO survey. As the survey responses have been submitted by the national authorities, FAO considers that they are official responses. However, owing to the differences in methods, frequency and precision of monitoring applied to LLP/AP incidents, the data may not perfectly correspond to the actual events monitored elsewhere.

Acronyms

AA	asynchronous approvals
AP	adventitious presence
CBD	Convention on Biological Diversity
CEPII	Centre d'Etudes Prospectives et d'Informations Internationales
DNA	deoxyribonucleic acid
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GM	genetically modified
GMO	genetically modified organism
ISAAA	International Service for the Acquisition of Agri-biotech Applications
LLP	low level presence
LMO	living modified organism
OECD	Organisation for Economic Co-operation and Development
r-DNA	recombinant deoxyribonucleic acid
2SLS	two-stage least squares
SPS	sanitary and phytosanitary measures
TRIPs	Trade-related Aspects of Intellectual Property Rights
TBT	Technical Barriers to Trade
WDI	World Development Indicators
WHO	World Health Organization
WTO	World Trade Organization

Abstract

The low level presence (LLP) and adventitious presence (AP) of genetically modified organisms (GMOs) in internationally traded food crops have become a major focus of discussion. The production (research and commercial use) of genetically modified (GM) food crops is increasing in both developed and developing nations, but countries have quite diverse GMO regulations. Asynchronous approvals (AA) and zero tolerance policies have been reported by some exporters to have a trade diversion effect. Therefore, the Food and Agriculture Organization of the United Nations (FAO) has conducted a survey to evaluate the issue and an econometric analysis to examine the impact of LLP on trade flows. Almost half of the survey respondents indicated that their countries produce GM crops for research or commercial use. However, only 47 percent of the respondents indicated that they have the technical capacity to detect GMOs in imports, and 35 percent indicated that they had faced LLP in their imports during the last 10 years. The main crops that are subject to LLP incidents are linseed, rice, maize and soybean. The most important factors that contribute to the trade risk are indicated to be the different policies on GMOs that exist between trading partners, unintentional movement of GM crops, and the asynchronous timing of approvals. Economic analysis found some evidence of the impact of restrictive regulations, including zero tolerance, on the maize trade. Restrictive LLP thresholds were found to have a somewhat ambiguous impact; they were insignificant in an ad hoc model, but had a mild deterrent effect on bilateral export flows in a theoretical model. On the other hand, the FAO survey reveals some incidents reported by importing countries related to LLP/AP. Generally, the situation is handled through rejection or market withdrawals by importers in developed countries. These incidents may have several socio-economic impacts on producers, consumers and agribusiness firms.

Introduction

The land area under cultivation with genetically modified organisms (GMOs) has grown steadily over the last two decades, with many genetically modified (GM) crops[1] important in international trade. Current systems of production, handling and transportation can lead to the unintentional low level presence of GMOs in non-GMO consignments. However, national policies and regulations that govern the acceptability of GM crops vary, and a number of trade-related problems have been reported as a result of the unintentional mixing of GM and non-GM crops. To examine the specific impact on agricultural trade flows, FAO conducted a survey to increase understanding of the extent of trade disruption due to the low level presence (LLP) and adventitious presence (AP)[2] of GMOs and an econometric analysis to estimate the extent to which regulations associated with LLP may cause trade disruption. The main objective of this paper is, therefore, to review and analyse the current production, trade and trade-related regulations of GM food crops, and to provide evidence on the possible impact of LLP on trade flow.

This study first reviews the current situation of GM crops in terms of production, trade and related regulations, with a comprehensive literature review of previous studies that have investigated the impacts of GM and LLP on trade and welfare. The following section analyses the responses to a survey administered by FAO. Section 3 explains how trade flow data may be employed within a bilateral trade flow model to examine the impact of GM-related regulations and LLP on trade flow.

1. Review of the current situation

Genetically modified crops

Biotechnology involves a wide range of technologies that can be applied for a range of different purposes, such as the genetic improvement of plant varieties and animal populations to increase their yields or efficiency, genetic characterization and conservation of genetic resources, diagnosis of disease in plants or animals, vaccine development and improvement of feeds (FAO, 2011a). One of these biotechnologies is genetic modification, which may be used to produce GMOs. A GMO refers to an organism that has been transformed by the insertion of one or more transgenes (FAO, 2001). In line with the rapid advances in biotechnology, a number of GM crops have been developed and released for commercial agriculture production (see FAO, 2011b). In addition, a recent FAO e-mail conference indicated that in the near future the new GMOs likely to be released would continue to centre around four crops (soybean, maize, cotton and canola) and two traits (herbicide tolerance and insect resistance), but that they would also include a broad range of additional species and trait combinations (Ruane, 2013).

The increasing cultivation of GM crops has raised a wide range of concerns related to food safety, environmental effects and socio-economic issues. From the food and health perspective, the main concerns are related to possible toxicity and allergenicity of GM foods and products. Concerns about environmental risks include the impact of introgression of the transgenes into the natural landscape, the

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[1] GM crops: A genetically modified (GM) crop refers to a recombinant-deoxyribonucleic acid (r-DNA) plant. An r-DNA plant is a plant in which the genetic material has been changed through *in vitro* nucleic acid techniques, including r-DNA injection and direct injection of nucleic acid into cells or organelles.

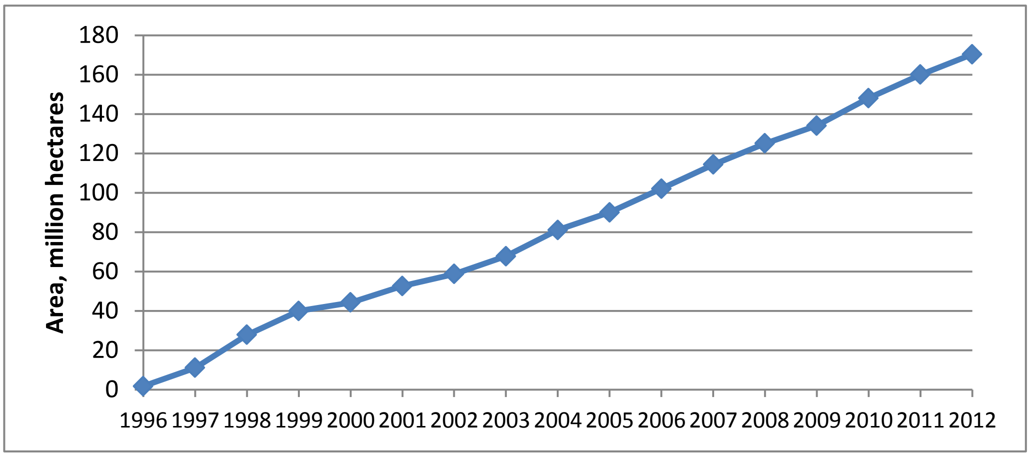
[2] Low level presence (LLP): LLP refers to the detection of low levels of GM crops that have been approved in at least one country on the basis of a food safety assessment according to the relevant Codex guidelines. Readers should note that low level presence (LLP) is not specifically defined by Codex, however in the context of the Codex guidelines it is referred to as LLP. Adventitious presence (AP): AP refers to detection of the unintentional presence of GM crops that have not been approved in any countries on the basis of a food safety assessment according to the relevant Codex guidelines.

impact of gene flow, the effect on non-target organisms, evolution of pest resistance and loss of biodiversity. The social and ethical concerns relate to restrictions on access to genetic resources and new technologies, loss of traditions such as saving seeds, private sector monopoly and loss of income for resource-poor farmers (FAO, 2012).

Production

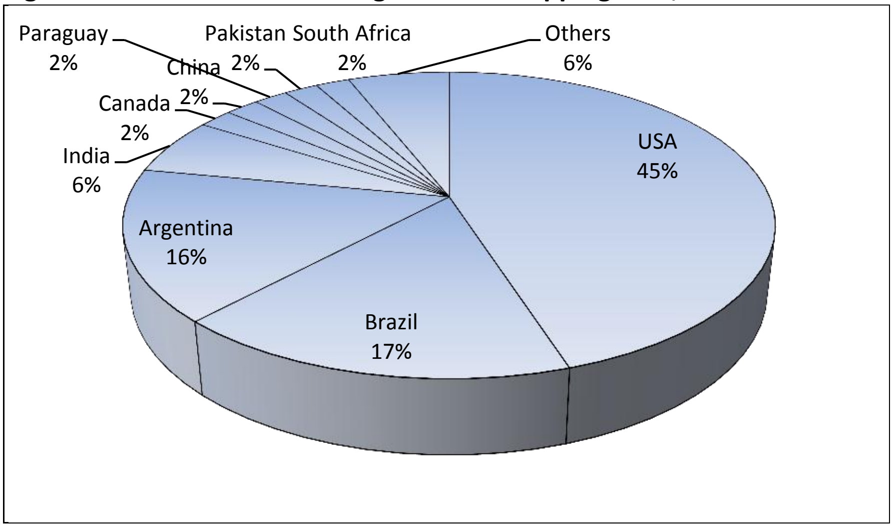
The total area of GM crops had risen to 170 million hectares by at the end of 2012 (Figure 1). The main growers of GM crops are the United States, Brazil and Argentina, while India, Canada and China also are important producers (Figure 2).

Figure 1. Global area of GM crops, 1996–2012



Source: Compiled from James, 2010, 2013.

Figure 2. Share of countries in global GM cropping area, 2010



Source: Compiled from James, 2010.

According to the report of the International Service for the Acquisition of Agri-biotech Applications (ISAAA[3]; James, 2013), in 2012 developing countries accounted for 52 percent of the area planted with GM crops globally, while developed countries accounted for 48 percent. Soybean ranks first (almost 50 percent) among the total GM crops planted, followed by maize and cotton (Figure 3). The proportion of

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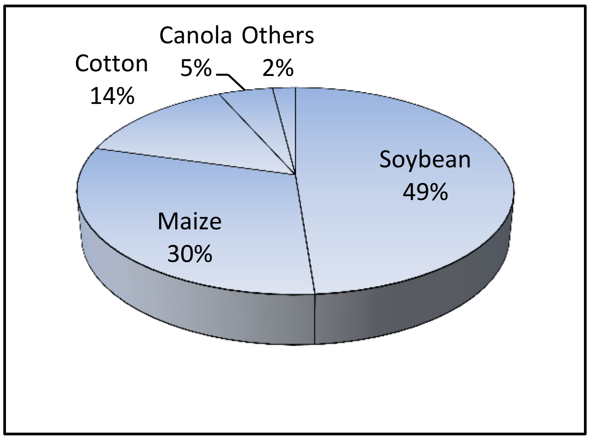
[3] There are limited sources that report the statistics of GM crops on a global scale. Therefore the ISAAA reports (2010–2013) were utilized in reporting the recent statistics.

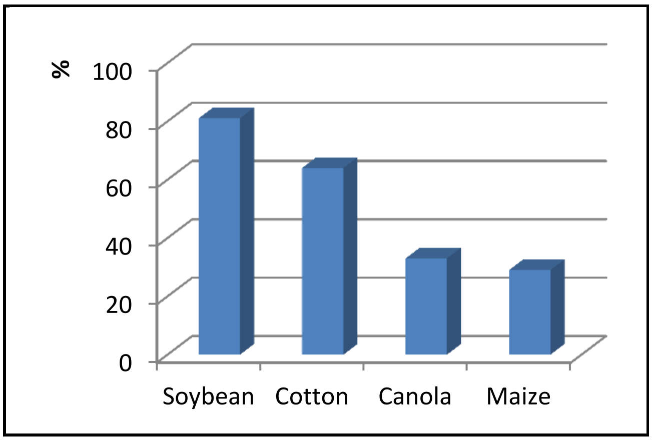
each GM crop in the total area planted was: 81 percent for soybean, 64 percent for cotton, 33 percent for canola and 29 percent for maize (Figure 4).

Figure 3. Distribution of GM crops in total GM crop area, 2010



Source: Compiled from James, 2010.

Figure 4. Proportion of GM crop as a percentage of total individual area under that crop, 2010



Source: Compiled from James, 2010.

GMO regulations and policies

According to ISAAA (James, 2010), 29 countries planted commercialized GM crops in 2010 and an additional 30 countries have granted regulatory approvals for GM crops for import, food and feed use, and for release into the environment, since 1996. The GMO regulations and policies vary by country, with some countries applying private standards and zero tolerance policies. In general, a zero tolerance policy states that any imported food or feed material cannot contain even trace amounts of GMO substances that have not been authorized in the importing country.

In order to address the LLP issue, a partial solution has been adopted by some countries. For example, EU regulation No 619/2011, in force since July 2011, lays down the methods of sampling and analysis for the official control related to GMOs in feed. This regulation sets a threshold level of 0.1 percent for feed, a so-called “technical solution”. However, for food and seed this threshold is 0 percent. Some critiques have been put forward by the exporters of GM crops on the adaptation of this zero tolerance policy by neighbouring or food importing countries, and concerns have been raised over the impact on trade flows caused by the LLP incidents. Another argument initiated by the exporters relates to “asynchronous approvals” (AA), i.e. approvals granted by one importing country but still pending in another. The issue of AA reportedly leads to delays and additional costs to traders.

International agreements, guidelines, and relevant activities on food, feed, environmental safety, and trade

Food and feed: The Codex Alimentarius Commission, established in 1963 by the FAO and the World Health Organization (WHO), develops harmonized international food standards, guidelines and codes of practice to protect the health of consumers and ensure fair practices in food trade. While comprising recommendations for voluntary application by members, Codex standards serve in many cases as a basis for national legislation. The reference made to Codex food safety standards in the World Trade Organization’s Agreement on Sanitary and Phytosanitary measures (SPS Agreement) means that Codex has a role in resolving trade disputes. The programme of the Organisation for Economic Co-operation and Development (OECD) Task Force for the Safety of Novel Foods and Feeds aims to promote international harmonization in the risk/safety assessment of novel foods and feeds by encouraging information sharing, promoting harmonized practices and common frameworks in safety assessment and regulation, and preventing duplication of effort among countries (OECD, 2013).

Environment: The OECD's Working Group on Harmonization of Regulatory Oversight in Biotechnology deals with the environmental risk/safety assessment of transgenic plants and other genetically engineered organisms. The work aims to ensure that the types of elements used in biosafety assessment, as well as the methods used to collect such information, are as similar as possible among countries. The Cartagena Protocol on Biosafety to the Convention on Biological Diversity (CBD) is an international agreement that aims to ensure the safe handling, transport and use of living modified organisms (LMOs) resulting from modern biotechnology that may have adverse effects on biological diversity (CBD, 2013). It was adopted on 29 January 2000 and came into force on 11 September 2003. The protocol lays down rules for international trade in LMOs, which are basically GMOs that have not been processed, and that could live if introduced into the environment, such as seeds. Under the protocol, a country that wants to export LMOs for intentional introduction into the environment (such as seeds for planting) must seek, in advance, informed agreement from the importing country before the first shipment takes place. The Biosafety Protocol requires parties to make decisions on the import of LMOs for intentional introduction into the environment in accordance with scientifically sound risk assessments.

Trade: The Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement) is an international treaty of the World Trade Organization (WTO). It was negotiated during the Uruguay Round and came into force with the establishment of the WTO in 1995. The concerns of food producers in developing countries over SPS measures applied by developed countries have been reported as a major SPS issue (WTO, 2013). The SPS Agreement indicates that measures have to be based either on scientific evidence of risk or on recognized international standards. Countries are free to set their own standards if they are based on science. In addition, the Agreement on Technical Barriers to Trade (TBT) and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) are indirectly related WTO agreements that promote the development of international standards, encourage recognition of other countries' measures and seek to find an appropriate balance between the interests of users and creators of intellectual property.

Economic effects of GM crops

An overview of previous research findings is summarized in Table 1. All of the studies reviewed examine the impact that the production of GM crops has on either welfare or trade, and they generally find welfare gains for the producers. However, strict regulations implemented by importers lead to trade distortions because of the higher associated costs. The current study aims to add to the existing research by identifying the intensity of the LLP issue as well as future trends.

Table 1. Selected literature review

Source	Method	Commodity analysed	Findings
Anderson and Jackson (2005)	Global Trade Analysis Project	GM varieties of various grains and oilseeds	Gross economic benefits to farmers from adopting GM crops under a variety of scenarios could be positive even if the strict controls on imports from GM-adopting countries imposed by the European Union (EU) are maintained.
Sobolevsky *et al.* (2005)	Partial equilibrium four-region world trade model	Roundup Ready (RR) soybean	The USA, Argentina, Brazil, and the Rest of the World all gain from the introduction of RR soybeans although some groups may lose.
Gruere *et al.* (2007)	Multi-country general equilibrium model	GM field crops (rice, wheat, maize, soybean and cotton)	The gains associated with the adoption of GM food crops largely exceed any type of potential trade losses these countries may incur. Adopting GM crops also allows net importing countries to reduce their imports greatly.
Vigani *et al*. (2009)	Trade flow	Food trade	Bilateral variations in GMO regulations negatively affect trade flows. Main impeding factors are the approval process, labelling policies and traceability requirements.
Bouet *et al*. (2011)	Spatial equilibrium model	Maize and soybean	Information requirements (labelling) would have greater effects on trade, creating significant trade distortion that diverts exports from their original destination.
Gruere (2009)	Analytical model	Maize and soybean	A GM ban is the most costly option, and can only be justified if the country does not import that crop or perceived risks exceed the cost. An LLP policy with a 0 percent tolerance level is almost identical.
Kalaitzandonakes *et al*. (2011)	Spatial equilibrium model	Maize	Smaller Latin American importing countries are likely to experience 2–8 percent price increases as a result of trade disruptions, whereas larger importers would experience price increases of 9–20 percent caused by a zero tolerance level for LLP.

2. Results of the FAO survey on accidental presence of low levels of genetically modified organisms (GMOs) in internationally traded food crops

Summary analysis of survey results

The survey[4] consisted of 21 questions related to GM crops, including their production, regulation, safety assessment, detection and quantification, LLP/AP incidents, and the importance of factors contributing to the trade risks posed by LLP/AP. It was sent to a total of 193[5] countries, including 28 EU Member States with a response rate of 39 percent[6]. The distribution of regional responses is presented in Figure 5.

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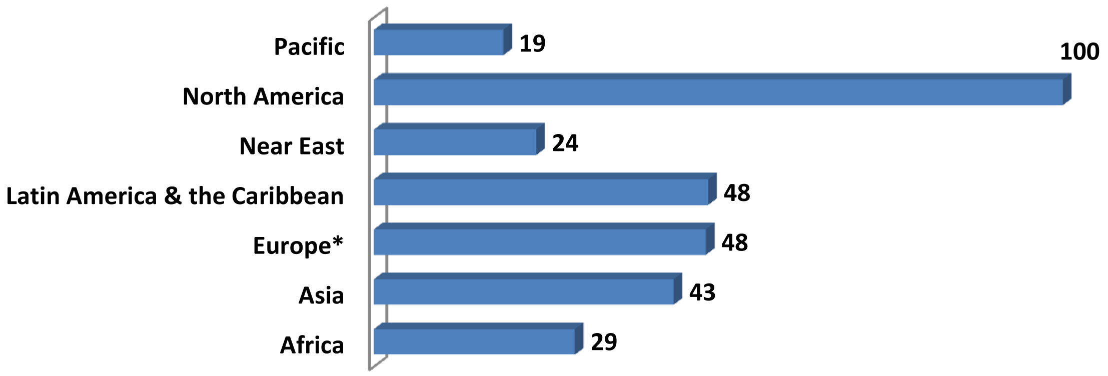
[4] The survey was sent to national government organizations through FAO Representations (FAORs), Codex contact points, and individual contacts in early 2013.
[5] The number includes European Union (EU).
[6] The list of responding countries: Argentina, Australia, Austria, Bahamas, Bangladesh, Barbados, Bolivia, Botswana, Brazil, Bulgaria, Cambodia, Canada, Cape Verde, Colombia, DR Congo, Congo Republic, Costa Rica, Croatia, Cuba, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, El Salvador, Estonia, European Union, Finland, France, Gambia, Germany, Grenada, Honduras, Hungary, Iran, Ireland, Italy, Jamaica, Japan, Lao PDR, Latvia,

Figure 5. Distribution of regional responses (%)



* includes European Union

GM crop production

In total, 59 percent of responding countries indicated that they do not produce GM crops, 19 percent indicated production for research only and the remaining 22 percent indicated both research and commercial production. Among the countries that reported the production of GM crops, 53 percent indicated that the number of GM (production) events was lower than 20 and 3 percent indicated that it was over 80. Fifty-three percent of respondents indicated that the number of GM crops in the pipeline was lower than 20 while 5 percent indicated that the number of events in the pipeline was between 51 and 80. 41 percent of respondents reported that number of GM crops authorized to be commercialized was lower than 20 while 4 percent indicated that the number was over 80.

Trade in GM crops

Some of the respondents reported the proportion of GM crops imported as a proportion of total trade imports of the crop commodity. For instance, 81 percent of soy imported by Austria from the United States and Brazil, 99 percent of maize imported by Bolivia from Argentina and Brazil, and 90 percent of maize and soy imported by the Philippines from the United States and Argentina was reported to be GM.

Regulations on GM crops

Seventy-seven percent of respondents indicated that they have a GMO regulation and 73 percent of respondents stated that they have zero tolerance for unauthorized GM crops.

Safety assessment of GM crops

Sixty-six percent of the respondents reported that they perform food safety assessment. Around 64 percent perform feed safety assessment, 70 percent perform environmental safety assessment and

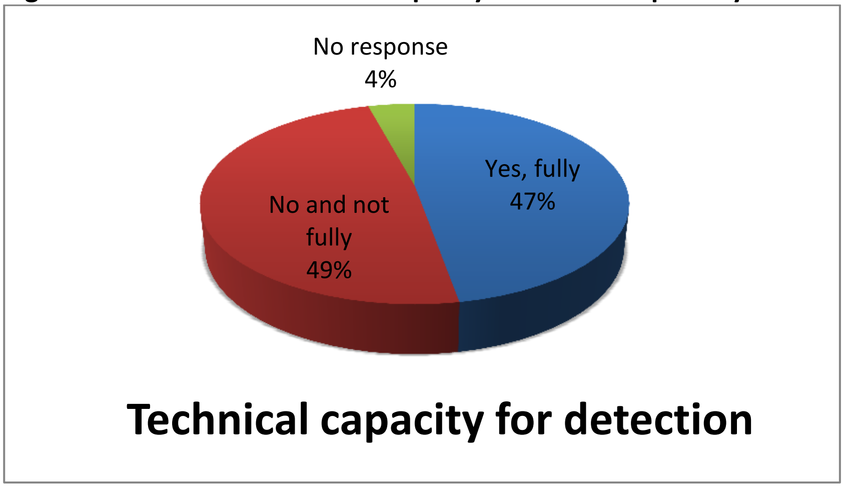
Lithuania, Luxembourg, Madagascar, Malaysia, Mali, Moldova, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Netherlands, New Zealand, Niger, Norway, Pakistan, Philippines, Poland, Qatar, Samoa, Seychelles, Slovakia, Slovenia, Somalia, Spain, Sudan, Sweden, Syria, Thailand, Togo, Trinidad, Turkey, Uruguay, United States of America.

almost 69 percent of the respondents indicated that they have an authorization policy (domestic, regional, etc.) and 18 percent reported that they do not permit any GM crops to enter the country.

Detection and quantification

Fifty-four percent of respondents stated that they have no LLP/AP threshold, while 34 percent indicated that they do, although this is mostly for feed (EU technical solution). It can be concluded that most countries do not have a threshold level for LLP/AP for food. Slightly less than half of the respondents indicated that they have the full technical capacity to detect or quantify GMOs according to the Codex guidelines (Figure 6).

Figure 6. Existence of technical capacity to detect or quantify GMOs according to Codex guidelines



LLP and AP incidents

In total, 35 percent reported that they had faced LLP or AP incidents in the last 10 years and 50 percent said they had not. The United States, China and Canada are the three major exporting countries, and linseed, rice and maize are the major commodities associated with the LLP/AP incidents, based on the reports of the respondents (Figures 7 and 8). Given the fact that these countries are important producers of GM crops, the incidents are expected to be related to the levels of production and export. However, it should be noted that the figure does not reflect the volume of incidents.

Figure 7. Number of LLP/AP incidents by country of origin

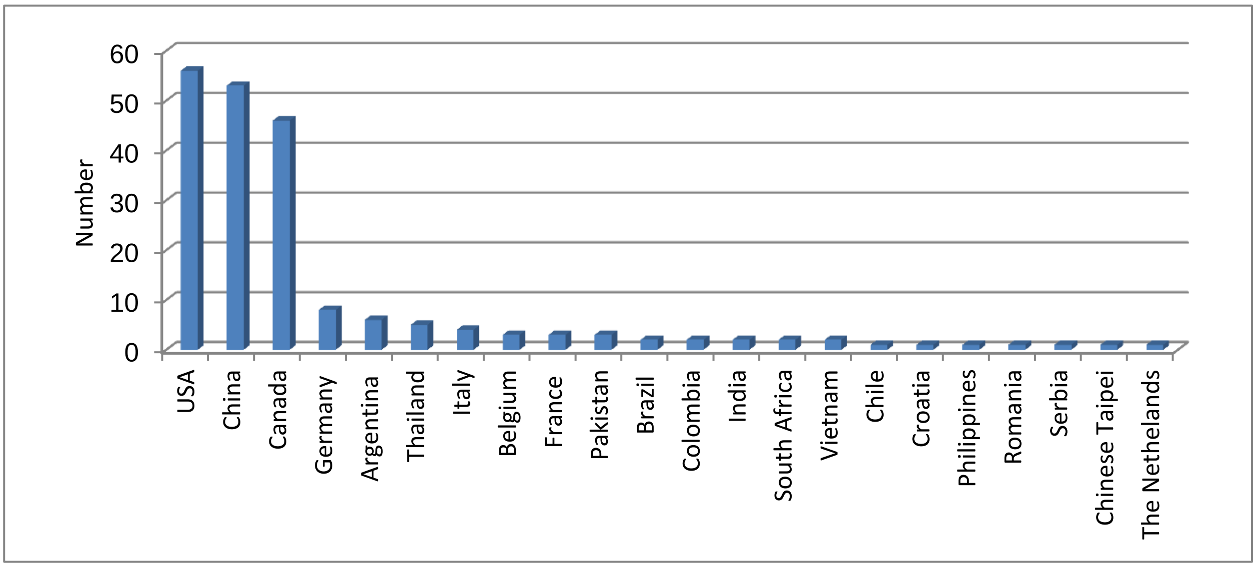
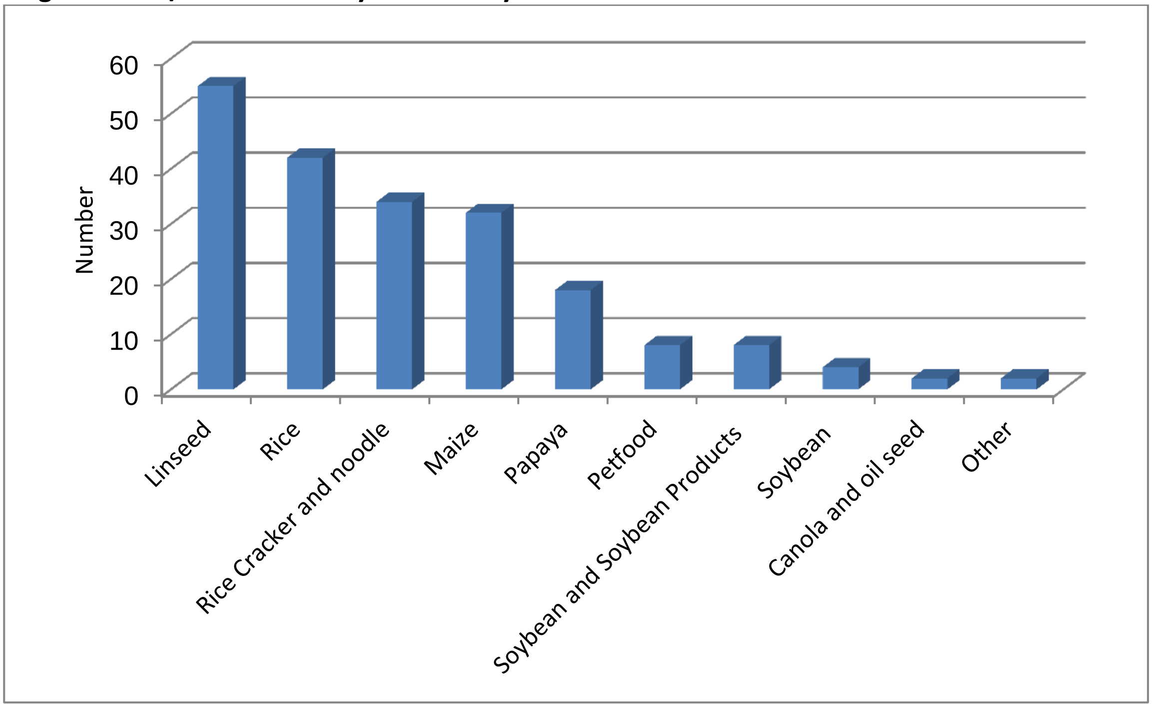
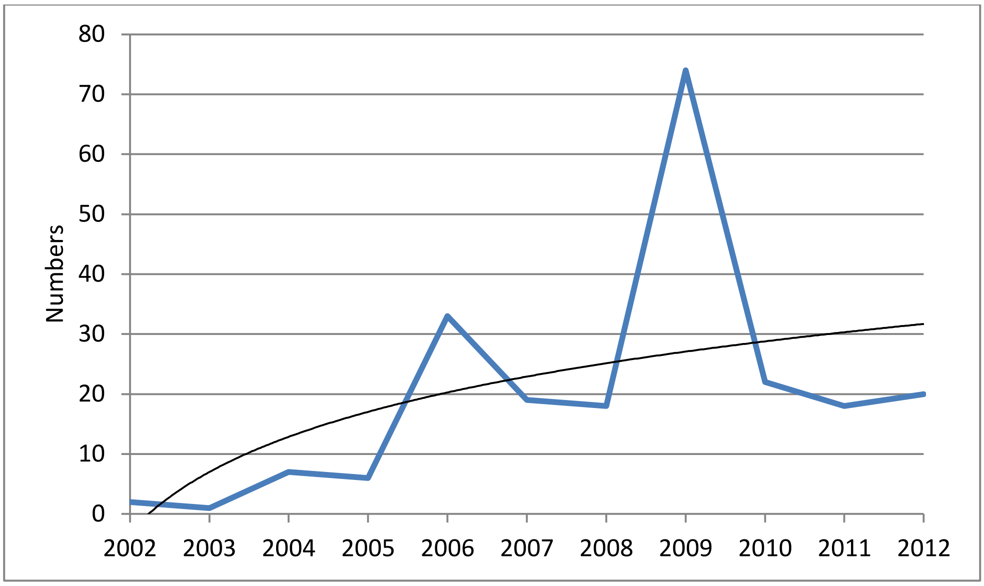


Figure 8. LLP/AP incidents by commodity



The number of LLP/AP incidents in general has an increasing trend. The number of incidents peaked in 2009, and has subsequently levelled off (Figure 9).

Figure 9. Number of LLP/AP incidents and trend (2002–2012)



Importance of factors contributing to the trade risks posed by LLP/AP

According to the survey respondents, the most important factors that contribute to the trade risk are: the existence of different policies on GMOs among trading partners (42 percent of countries stated that this issue is very important); unintentional movement of GM crops (39 percent of countries stated that this is very important); and different timing of approvals (35 percent of countries stated that this is very important). Some countries specified other related issues such as lack of legislative framework and difficulty in accessing information for some products.

3. Econometric analysis of the effect of LLP on trade flow: The case of maize[7]

Maize is a widely traded agricultural commodity. According to FAOSTAT, the amount of maize traded was 107 million MT in 2010, valued at about US$26 billion (FAOSTAT, 2013). In this study maize was chosen to test the impact of LLP/AP partly because it is a major commodity subject to trade and also because, in the FAO survey, it was reported as one of the major commodities associated with LLP incidents by the respondents (around 30 incidents in the last 10 years).

Empirical model and data

A bilateral export flow model was employed, utilizing cross-sectional data. Although the theoretical foundations and estimation issues are constantly updated (Evenett and Keller, 1998; Anderson and van Wincoop, 2003; Baier and Bergstrand, 2007), these models are widely used because of their usefulness in trade policy analyses, and agriculture related applications can be found in a number of recent studies (Anders and Caswell, 2009; Jongwanich, 2009; Vollrath *et al.*, 2009). Gravity-type trade flow models assume that bilateral trade between partner countries increases with size (income, population, etc.) and closeness. The main model utilized in the study can be described as:

$$lnE_{ij} = ln\alpha + \beta_1 lnY_i + \beta_2 lnY_j + \beta_3 lnD_{ij} + \beta_4 lnReg\text{-}Index_j + \beta_5 lnLLP_j + ln\varepsilon_{ij}$$

[7] In this chapter, all analyses were conducted using a subset of the FAO survey responses.

where E: bilateral export flow between countries i and j, in volume; Y_i: gross domestic product (GDP) of exporting country; Y_j: GDP of importing country; D_{ij}: distance between exporting and importing countries; $Reg\text{-}Index_j$: GMO regulation index of importing country; LLP_j: LLP threshold of the importing country; α: constant; β: parameter; ε_{ij}: residual term.

The regulation index is similar to that used by Vigani *et al*. (2009). However, their index includes six factors (approval process, risk assessment, labelling policies, traceability system, coexistence guidelines and membership in international GMO related agreements) while the index in this analysis covers 12 factors[8]. The GMO regulation index is composed on the basis of the questions answered in the survey and EU Food Safety Regulation EC-178/2002 (EU, 2002).

To estimate the impact of GMO regulation and LLP, five different models were developed. The first two models (Models 1 and 2) estimate the impact of GMO regulation together with conventional trade flow variables (income, population, distance). For the LLP thresholds, three different methods were used, based on the various assumptions, because of inconsistencies in the responses to the survey. Model 3 assumes that the LLP variable takes either the value 0.1, a technical solution for the EU members for feed import, according to EU-619/2011 (EU, 2011), or 10 for countries that do not have the threshold. Model 4 assumes that the LLP threshold includes other factors, taking into account not only reported threshold levels but also a combination of other factors such as zero tolerance and existence of GMO regulation. Finally, Model 5 assumes that the LLP variable takes the value 0.1 (as before) for the EU members, and 1 for other countries, controlling for EU internal trade.

The analysis utilized 2011 bilateral maize exports among the 64 countries that responded to the FAO survey. There were 582 observations covering 4656 data points. Data on export flows were derived from Comtrade (2013), data on GDP and population from World Bank's World Development Indicators (WDI) (WTO, 2013), and bilateral distance data from the French Centre d'Etudes Prospectives et d'Informations Internationales (CEPII, 2013).

Results and discussion

The results of the estimation are presented in Table 2. The robust estimation results indicate that the GDPs of exporting and importing countries are positively related to the trade flow of maize. For instance, a 1 percent increase in the income level of the importing country leads to 0.84 percent higher trade flow. The distance variable, a proxy for transportation cost, was found to be negative and significant, meaning that trade flow is lower between more distant partners. The regulation variable was found to be negative and significant at the 10 percent level (columns 1 and 2). This implies that a more restrictive GMO regulation has a deterrent effect on maize trade flow. Models 3 and 4 (columns 3 and 4) indicate that LLP does not have a significant impact on trade flow, while model 5 suggests that the impact of LLP on trade flow is significant but negative. Keeping in mind that restrictive thresholds have lower limits, this mainly shows that, even where EU internal trade is taken into account, the LLP threshold has no deterrent effect on bilateral exports. In order to test and eliminate the problem of endogeneity (causality between independent and dependent variables), an endogeneity test was first carried out, the validity of instruments checked, and the model was then re-estimated using two-stage least squares (2SLS) for the LLP threshold. The results confirmed that the LLP threshold is not endogenous, highlighting the lack of significance of that variable.

[8] These factors are: existence of food, feed, and environmental regulation; safety risk assessment; labelling requirement; LLP test requirement; traceability requirement; socio-economic assessment; existence of zero tolerance for unauthorized GM crops; conducting food, feed, and environmental safety assessments according to international guidelines; restrictiveness of authorization policy; testing requirement form exporting country; technical capacity to detect GMOs; detection methods utilized.

Table 2. Result of regression analysis of bilateral maize export flow
(*Dependent variable: natural logarithm of the bilateral export flow between countries* i *and* j*, in terms of volume*)

Variable	[Model 1] (GMO regulation impact)	[Model 2] (GMO regulation impact)	[Model 3] (LLP impact)	[Model 4] (LLP impact)	[Model 5] (LLP impact)
Constant	–10.28 (–3.43***)	–10.28 (–3.43***)	–10.68 (–3.99***)	–10.73 (–3.98***)	–5.22 (–1.89*)
Ln-Y_i	1.00 (10.20***)	–	–	–	–
Ln-Y_j	0.84 (9.23***)	–	–	–	–
Ln-$GDPC_i$	–1.70 (–7.72***)	–0.69 (–3.76***)	–0.69 (–4.08***)	–0.68 (–3.94***)	–0.64 (–3.68***)
Ln-$GDPC_j$	–0.56 (–3.43***)	0.28 (2.10**)	–	–	–
Ln-P_i	–	1.00 (10.21***)	1.03 (10.47***)	1.01 (10.23***)	0.72 (6.62***)
Ln-P_j	–	0.84 (9.23***)	0.86 (9.39***)	0.86 (9.44***)	0.81 (8.80***)
Ln-D_{ij}	–0.97 (–8.68***)	–0.97 (–8.68***)	–0.92 (–8.20***)	–0.93 (–8.35***)	–0.90 (–7.17***)
Ln-Reg-$Index_j$	–0.49 (–1.70*)	–0.49 (–1.70*)	–	–	–
Ln-LLP_j		–	–0.10 (–1.48)	–0.17 (–1.48)	–0.24 (–2.10**)
R^2	0.23	0.23	0.22	0.22	0.18
F	28.21***	28.21***	32.63***	33.10***	26.03***
Schwarz B.I.C.	1468	1468	1467	1467	1481
N	582	582	582	582	582

Note: in Tables 2 and 3, *t* values are in parentheses; *, ** and *** denote 10%, 5% and 1% significance, respectively. Y_i: GDP of exporting country; Y_j: GDP of importing country; $GDPC_i$: GDP per capita of exporting country; $GDPC_j$: GDP per capita of importing country; P_i: population of exporting country; P_j: population of importing country; D_{ij}: distance between partner countries; *Reg-Index*$_{j:}$ GMO regulation index of importing country; LLP_j: LLP threshold of importing country.

Table 3 presents the results of theoretically robust trade flow regression analysis based on importer and exporter fixed effects and focusing on the GMO regulation index (Model 6) and LLP threshold (Model 7) of importing countries. The inclusion of fixed effects yielded similar results for the regulation index, the parameter value for distance increased to unity, and the LLP variable became significant, although only at the 10 percent level.

Table 3. Maize export flow regression with country fixed effects

(*Dependent variable: natural logarithm of the ratio of export flow to product of incomes*) Variable	[Model 6] (Regulation impact)	[Model 7] (LLP impact)
Ln-D$_{ij}$	–1.35*** (–11.94)	–1.48*** (–13.00)
Ln-Reg-Index$_j$	–0.63** (–2.25)	–
Ln-LLP$_j$	–	0.20* (1.79)
R^2	0.41	0.40
F	5.26***	5.12***
N	582	582

Conclusions

This study aimed to examine the current production, trade and regulation issues related to GM crops on a global scale and the impact of LLP/AP of GM crops on trade flow. These issues were evaluated by utilizing available statistics, a related literature review, a survey and an econometric analysis. As the FAO survey highlighted, many responding countries (41 percent) produce GM crops for commercial or research purposes. However, 49 percent of the respondents indicated that they have no, or limited, technical capacity to detect GMOs according to Codex guidelines. Therefore, capacity development and technical assistance are essential, particularly for developing countries. Some of the respondents (35 percent) indicated that they had faced LLP/AP incidents in their imports over the last decade. Given the fact that more countries are producing GM crops every year and there are GM events in the pipeline, it is probable that more LLP/AP incidents will be observed in the future.

Employing a bilateral trade flow model and utilizing cross-sectional data, including the responses to the FAO survey, the study found that the restrictiveness of regulations, including zero tolerance, does have a deterrent impact on maize trade. However, the restrictive LLP threshold itself has a limited deterrent effect on bilateral export flows in general. The FAO survey revealed some incidents reported by importing countries related to LLP/AP. Generally, such situations are handled through rejection or market withdrawals by importers in developed countries, but in some cases consignments were accepted by some developing countries because of the lack of regulation. These incidents may have socio-economic impacts on producers, consumers and agribusiness firms. The occurrence of incidents beyond a certain level can lead to income loss for exporters and consequently for producers, and consumers in importing countries can face higher domestic prices when imports are restricted. The results of the econometric study were similar to previous findings that favour non-zero tolerance policies from the perspective of regulation restrictiveness, but suggest caution in assessing the impact of LLP itself on trade flows because this was estimated to be insignificant in the ad hoc model, while the theoretically robust estimation yielded a negative impact at the margin.

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