



CEE review 11-002

WHAT ARE THE FARM-LEVEL ECONOMIC IMPACTS OF THE GLOBAL CULTIVATION OF GM CROPS?

Systematic Review Protocol

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1. Background

The commercial application of genetically modified (GM) technology in agriculture began in the 1990s in the USA. The introduction of GM crops started with a small number of crop types, notably soya engineered to be resistant to certain types of herbicide, and oilseed rape (OSR) with similar modifications (known as HT crops, after 'herbicide tolerant'). This has since developed into widespread adoption, in a number of countries, of additional GM crops, including maize and cotton engineered to contain soil bacterium proteins that are toxic to certain pests (known as Bt crops, after the soil bacterium 'Bacillus thuringiensis') (Hall, 2010).

There have been many studies, reports and publications that have made claims about the economic impacts of the cultivation of GM crops globally. The diversity of the studies and the often apparently contradictory claims make it difficult to obtain an overview of the impacts. For example, impact has been addressed at the global level, national level, regional and farm level. After discussion with the funders this study will focus on the farm level impacts.

At the farm-level, numerous claims are made about the impacts of GM crop technology. In terms of economic impacts, the cultivation of GM crops involves potential revenue and cost impacts when compared with conventional crops. Notably, the farm-level profitability of GM crops is influenced by variables such as differences in yield, reductions in insecticide costs or weed management costs (depending on the modification present), differences in seed prices, and differences in price received by the farmer between the GM crop and its conventional counterpart (Gomez-Barbero & Rodriguez-Cerezo, 2006).

In detail, one farm-level impact of herbicide tolerant (HT) crops is the simplification of weed control. Farmers growing HT crops can use the application of one, broad-spectrum herbicide that kills most weeds but leaves the crop unharmed, as opposed to multiple applications of different herbicides at different times of the growing season (Hall, 2010). Farmers have therefore identified positive impacts of HT crops as being simplified management, greater flexibility because of there being a wider window available for spray applications, and less spraying, all of which have impacts in terms of costs, the environment and labour time (Oreszczyn, 2005).

These are only some of the claims that are found in the literature relating to the potential impacts of cultivating GM crops. However, the breadth and diversity of studies, and the vast body of literature, points to the need to synthesise and assess similar studies to provide a clear understanding of the body of evidence that exists. This is where the use of systematic review has value. Systematic reviews are different to so-called traditional literature reviews in that the process of review should be transparent, rigorous and replicable. It is considered a preferable option, particularly when there is a large body of evidence, and seeks to avoid the subjective selection of certain research findings that are considered by reviewers to be of most relevance or interest.

Thus this review aims to provide robust and accurate information about the farm-level economic impacts of global GM crop cultivation. A systematic review starts with a specific question or questions that is/are answerable in scientific terms. The questions

are central to the process because they generate the search terms used in the subsequent literature review and determine relevance criteria. In this case, the main question is:

- What are the farm-level economic impacts of the global cultivation of GM crops?¹

In the sections that follow, a detailed protocol is provided that describes how this question will be answered.

2. Objective of the Review

2.1 Primary question

What have been the farm-level economic impacts of commercial GM crop cultivation, as reported in literature published from January 2006 onwards².

Subject	Intervention	Outcomes	Comparators	Design
The farm-level economy	GM crop cultivation in the past 5 years. Any type of GM modification. Any GM crop.	Economic impacts at the farm level.	Conventional (non-GM) cropping systems.	Any study comparing before or after GM crop cultivation OR comparing changes during GM crop cultivation with a conventional crop OR comparing farms growing GM crops with farms not growing GM crops

The farm level economic impacts will be reviewed by searching for studies using the search terms detailed in section 3.1, and by utilising the inclusion and exclusion criteria detailed in section 3.3.

2.2 Issues to be addressed

The questions listed below reflect the issues that are likely to be addressed in the literature extracted during the review process. However, it must be borne in mind that the purpose of the review, and therefore the design of the review process, is to address the primary review question. Thus, whilst the review may produce answers to some of these questions, it is possible that literature extracted during the search process might not contain data that allows for these questions to be fully addressed. Even where the literature does contain data apparently relevant to these questions, a demonstrable link to GM cultivation may be lacking. To address this, a record will be maintained of all retrieved hits.

¹ Note that this review complements a second review in process concurrently that considers the environmental impacts of commercial GM crop cultivation (Knox et al).

² The funder (DEFRA) specified this date as the aim is to review research carried out since the GM Science Review Second Report (see: <http://www.bis.gov.uk/files/file14992.pdf>).

- Is there evidence that the commercialisation of GM crops has led to changes in on-farm labour costs?
- Is there evidence that the commercialisation of GM crops has led to changes in on-farm input costs?
- Is there evidence that the development and associated Intellectual Property (IP) and patent rights of GM crops has led to changes in farm costs?
- Is there evidence that the commercialisation of GM crops has led to changes in the profitability of farm businesses?
- Is there evidence that the commercialisation of GM crops has led to changes in farm household income?
- Is there evidence that the commercialisation of GM crops has led to changes in prices paid to farmers for their crops?
- Is there evidence that the adoption of GM crops has had an impact on farm structure?
- Is there evidence that the adoption of GM crops has had an impact on the size of farm operations in terms of land tenure?
- Is there evidence that the adoption of GM crops has had an impact on prices of products ex-farm gate (i.e. offered to consumers)?

3. Methods

3.1 Search strategy

In order to collate information for the study the following steps will be carried out.

The following search terms³ are proposed for use in the literature search.

((Genetic*\$modif*OR engineer*) OR GM OR transgen* OR herbicide\$toleran* OR insect\$resistan* OR BT OR biotech*) AND (econom* OR income* OR margin* OR price* OR cost* OR financ* OR revenue* OR profit* OR fee* OR labour)

The following databases will be scoped for usefulness and practicality, and subsequently may be searched:

- ISI Web of Knowledge
- ScienceDirect
- Copac (WWW.COPAC.AC.UK)
- CAB Abstracts
- Econlit
- Agecon ([HTTP://AGECONSEARCH.UMN.EDU/](http://AGECONSEARCH.UMN.EDU/))
- Index to theses online (WWW.THESES.COM)
- Agricola
- IBSS (International Bibliography of Social Science) Online

³ Consideration was originally given to the inclusion of trade names. However, searches for the trade names Amflora, Bollgard, LibertyLink, Liberty Link and Roundup Ready resulted in either no or only single figure hits in searches conducted in COPAC, IBSS and Econlit. Consequently tradenames were excluded from the keyword search terms.

- In addition, certain specialist publication and news websites will be scoped with the expectation that one or two will be searched for news of up-to-date reports, publications and studies. Sites for consideration are:
- Agbioworld www.agbioworld.org
- British Crop Production Council www.bcpc.org/publications/newsreleases.htm
- ABIC <http://www.abic.ca/newsletters.html>
- ISAAA ([HTTP://WWW.ISAAA.ORG/](http://WWW.ISAAA.ORG/)),
- GMO Compass ([HTTP://WWW.GMO-COMPASS.ORG/ENG/HOME/](http://WWW.GMO-COMPASS.ORG/ENG/HOME/)).

In addition, the following meta-search engines will be considered for inclusion in the search process:

- [HTTP://WWW.SCHOLAR.GOOGLE.COM](http://WWW.SCHOLAR.GOOGLE.COM)
- [HTTP://WWW.SCIRUS.COM](http://WWW.SCIRUS.COM)

Hit retrieval will be limited to the first 100 documents resulting from each search conducted using the online meta-search engines (ScholarGoogle and Scirus). Limiting retrieval in the meta-search engines to 100 hits is justified due to the limitations of time and database handling.

It should also be noted that the search strings and operators that search engines and databases utilise and accept, varies considerably, and, as such, the search process will need to be tailored as appropriate.

In general in systematic reviews there can be added value in searching out additional grey literature through specialist interest groups, industry bodies, NGOs, and so on. The specialist publication and news websites listed above will serve this purpose here. Further, given the topic under review, there may be certain confidential and commercial information that is potentially relevant. However, given the difficulty obtaining such publications, and the limited time and resources available, this is unlikely to be explored.

Further modifications may be made to the search criteria as the search is conducted. In all cases the changes in the search strategy will be fully documented.

3.2 Language

It is proposed that the scope of the study be restricted to searches conducted in English for English language studies only. It is acknowledged that there is likely to be a body of evidence from countries such as India, Spain, China and the South American continent in the languages of these countries. However, the task of searching, translating and including these would be too great to conduct within this review. At the request of the sponsors a scoping study was undertaken to assess the potential implications of limiting searching to the English language. Because Spain

and a number of south American countries cultivate GM crops, and are expected to be sources of potentially relevant material, Spanish was selected as the language comparator.

Searches were carried out in English and Spanish using two search engines (Web of Knowledge and ScienceDirect) and selected search terms from the identified list. Numbers of hits were compared and titles meeting the inclusion criteria assessed (see appendix 1). The following constraints to this scoping exercise are noted: first, one non-English language was used, and second, the search engines used favour the peer reviewed literature over grey literature.

The conclusion of the scoping exercise was that the decision to use English as the selected language is justified. This is so on the grounds that using alternative language search terms, in this case Spanish, resulted in either a failure to return any hits, produced only a very few hits that failed to meet the selection criteria, or produced a few hits that were in English and that would therefore potentially be identified elsewhere in the search process.

3.3 Study inclusion criteria

Criteria for including studies are as follows. Studies will first be assessed for inclusion based on the study title. The next stage will be to check for relevance by reading the abstract of those selected based on the title. The third stage will be to read the full text of those selected following reading of abstracts in order to establish relevance for final inclusion in the extraction and synthesis stages. At each stage, two reviewers will apply the inclusion/exclusion criteria to a random sample of 10% of the studies retrieved, to assess the repeatability of the process and to reduce reviewer bias. Kappa analysis will be performed and a rating of 0.5 or above will be required. If this is not achieved a third reviewer will address and resolve the disagreements between reviewers as to the application of the inclusion/exclusion criteria.

Relevant subject(s):

Studies must meet these relevant subject criteria:

- Unit of study must be farm level
- Any country.
- Any study published since January 2006.
- Any GM crop and modification (trait).

- **Types of intervention:**

GM crop cultivation.

- **Types of comparator:**

Situation prior to cultivation of GM crop and/or conventional crops grown at the same time and/or between GM/non-GM farms.

- **Types of outcome:**

Change in farm level economics (costs/income/profit/gross margins etc) since cultivation of GM crop.

- **Types of study:**

Acceptable study types include farm level interviews, farm income data analysis, farm level economic modelling.

- **Exclusion criteria**

Studies will be excluded that have looked at global economic welfare impacts, country level economic impacts, studies of environmental but not economic impacts, studies published prior to 2006.

3.4 Potential effect modifiers and reasons for heterogeneity:

It is noted that in many cases it may be difficult to separate the effects of changing to GM crops on, e.g., farm incomes, from other changes happening in global food and commodity markets, and within the wider economy, since many factors impact farm incomes, input prices, etc. These ‘non-GM’ impacts could include policy/regulatory changes that impact on farm incomes, changes in input costs (for example for fuel, agri-chemicals) that impact on farm profit margins, changes in world commodity prices that impact farm incomes and so on.

Another potential issue may be heterogeneity among farmers. Some farmers gain a lot from GM technology while others may have losses due to differences in physical and economic conditions on-farm. Hence, comparing individual farmers or comparing averages leads to a ‘homogeneity bias’ (Dillen *et al*, 2009; Demont *et al*, 2008).

3.5 Study quality assessment

Assessment of study quality is required to reduce the potential for the introduction of bias from studies that were poorly designed, implemented and/or reported. To reduce this bias, documents taken to the full text level of review will be ranked using a predetermined series of categories. To ensure consistency of ranking, a subset of the full text articles (not less than 10%) will be compared by two reviewers. Differences in ranking will be recorded and either resolved by consensus or the use of a third reviewer.

A number of tools exist that are designed to evaluate the quality of health economic studies. For example, the Quality of Health Economic Studies instrument is a 16 item tool (Ofman *et al*, 2003) (see appendix 2 for full list of items). It includes questions such as:

- Was the study objective presented in a clear, specific, and measurable manner?
- Were variable estimates used in the analysis from the best available source (i.e., randomized control trial - best, expert opinion - worst)? Was uncertainty handled by (1) statistical analysis to address random events, (2) sensitivity analysis to cover a range of assumptions?
- Were the conclusions/recommendations of the study justified and based on the study results?

In addition, the National Collaborating Centre for Mental Health (2009) provides a Quality checklist for economic studies. This tool contains 35 items, broken down into

three categories, namely, Study design, Data collection and Analysis and interpretation of results (see appendix 2 for full list of items).

Our study quality assessment will draw on tools such as these. The task of evaluating study quality will fall to members of the team with expertise in the area of economic studies. Their knowledge will be needed to establish quality criteria, drawing, where appropriate on pre-existing instruments such as the ones referred to above, and then to rate the quality of studies elicited during the search stage. The resultant quality assessment will be documented prior to implementation with any subsequent modifications noted. The process of quality assessment will also note whether studies are peer-reviewed or grey literature.

3.6 Data extraction strategy

The following data will be extracted:

- Study date,
- Country of study,
- Specific crop(s),
- Specific modification(s)/ trait(s),
- Study type,
- Outcome measure (economic indicator studied): eg farm income, seed costs, technology fees, gross margins, farm gate prices, price of end product, scale of farm business etc,
- Descriptive change in economic indicator studied (positive or negative impact), and
- Numerical/percentage change in economic indicator studied (where applicable).

3.7 Data synthesis and presentation

We envisage two different strands of data synthesis – one meta-analysis and one narrative review. Initially we will present data derived from the relevant studies in a series of tables, tabulating the extracted data using the categories listed in section 3.6 Data Extraction Strategy. This will provide an overview of the reviewed studies. This tabulation of extracted data will also facilitate decisions relating to data synthesis for the meta-analysis by clearly demonstrating what data are available for statistical analysis across studies.

4. Potential Conflicts of Interest and Sources of Support

There are no conflicts of interest and the study is funded by the UK Government Department for Environment, Food and Rural Affairs.

5. References

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Appendix 1: Scoping exercise using the Spanish language

The search terms selected for the economic search were 'Transgenic' AND 'Econom*', which translated to 'Transgenicos' AND 'Econom*' in Spanish.

The results of the searches were as follows.

- Web of Knowledge search on 29/10/10 using the terms 'Transgenic' AND 'Econom*' resulted in 537 hits, but the search for 'Transgenicos' AND 'Econom*' resulted in a single hit. Review of the title suggested that the paper, by Acosta et al. 2009, would be of interest to the study. It was also present within the English results.
- The Sciedirect search on the 29/10/10 using the terms 'Transgenic' AND 'Econom*' resulted in 94 hits. Using the Spanish terms 'Transgenicos' AND 'Econom*' resulted in no hits as 'Transgenicos' was not identified within the database.

'Transgenicos' is the common Spanish term for 'Genetically Modified', but to assess whether the lack of returned information was due to a problem with the selected search terminology, the databases were also searched with a literal translation. To do this, the term 'Genetically modified' was substituted for 'Geneticamente

modificados'. On ScienceDirect this returned five hits, none of which were relevant based on the study inclusion criteria. The 'Geneticamente modificados' term search on Web of Science resulted in two hits of which one (Garcia, 2004. Rev. Biol. Trop, 52 (3): 727-732) would have made the title screening criteria, although the abstract, title and paper are presented in English.

Appendix 2: Examples of quality checklists for economic studies

Checklist one:

1. Was the study objective presented in a clear, specific, and measurable manner?
2. Were the perspective of the analysis (societal, third-party payer, etc.) and reasons for its selection stated?
3. Were variable estimates used in the analysis from the best available source (i.e., randomized control trial - best, expert opinion - worst)?
4. If estimates came from a subgroup analysis, were the groups prespecified at the beginning of the study?
5. Was uncertainty handled by (1) statistical analysis to address random events, (2) sensitivity analysis to cover a range of assumptions?
6. Was incremental analysis performed between alternatives for resources and costs?
7. Was the methodology for data abstraction (including the value of health states and other benefits) stated?
8. Did the analytic horizon allow time for all relevant and important outcomes? Were benefits and costs that went beyond 1 year discounted (3% to 5%) and justification given for the discount rate?
9. Was the measurement of costs appropriate and the methodology for the estimation of quantities and unit costs clearly described?
10. Were the primary outcome measure(s) for the economic evaluation clearly stated and did they include the major short-term was justification given for the measures/scales used?
11. Were the health outcomes measures/scales valid and reliable? If previously tested valid and reliable measures were not available, was justification given for the measures/scales used?
12. Were the economic model (including structure), study methods and analysis, and the components of the numerator and denominator displayed in a clear, transparent manner?
13. Were the choice of economic model, main assumptions, and limitations of the study stated and justified?
14. Did the author(s) explicitly discuss direction and magnitude of potential biases?
15. Were the conclusions/recommendations of the study justified and based on the study results?
16. Was there a statement disclosing the source of funding for the study?

Checklist two:

- 1 The research question is stated
- 2 The economic importance of the research question is stated
- 3 The viewpoint(s) of the analysis are clearly stated and justified
- 4 The rationale for choosing the alternative programmes or interventions compared is stated

- 5 The alternatives being compared are clearly described
- 6 The form of economic evaluation is stated
- 7 The choice of form of economic evaluation used is justified in relation to the questions addressed

Data collection

- 1 The source of effectiveness estimates used is stated
- 2 Details of the design and results of effectiveness study are given (if based on a single study)
- 3 Details of the method of synthesis or meta-analysis of estimates are given (if based on an overview of a number of effectiveness studies)
- 4 The primary outcome measure(s) for the economic evaluation are clearly stated
- 5 Methods to value health states and other benefits are stated
- 6 Details of the subjects from whom valuations were obtained are given
- 7 Indirect costs (if included) are reported separately
- 8 The relevance of indirect costs to the study question is discussed
- 9 Quantities of resources are reported separately from their unit costs
- 10 Methods for the estimation of quantities and unit costs are described
- 11 Currency and price data are recorded
- 12 Details of currency, price adjustments for inflation or currency conversion are given
- 13 Details of any model used are given
- 14 The choice of model used and the key parameters on which it is based are justified

Analysis and interpretation of results

- 1 The time horizon of costs and benefits is stated
- 2 The discount rate(s) is stated
- 3 The choice of rate(s) is justified
- 4 An explanation is given if costs or benefits are not discounted
- 5 Details of statistical tests and confidence intervals are given for stochastic data
- 6 The approach to sensitivity analysis is given
- 7 The choice of variables for sensitivity analysis is given
- 8 The ranges over which the variables are varied are stated
- 9 Relevant alternatives are compared