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Environmental benefits and costs of transgenic crops: introduction

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Introduction

Concern about the environmental impacts of transgenic crops is one of the major reasons for the EU's quasi moratorium on GMOs (European Environment Council 1999). The contributions in this book show that the economic implications of these concerns are far-reaching and complex. At the centre of the theoretical framework for analysis stands the linear chain of agricultural biotechnology development as depicted in Figure 1. The public and private sector invest resources in the development and use of knowledge to produce agricultural crops with new traits. Those new crops are sold to farmers who plant them and sell the harvest to the downstream sector, which further processes the products until they finally reach the end consumer via the retailers. The major concern about environmental impact at the farm level, where the deliberate release into the environment takes place, is indicated by the circle around the box in the centre of Figure 1.

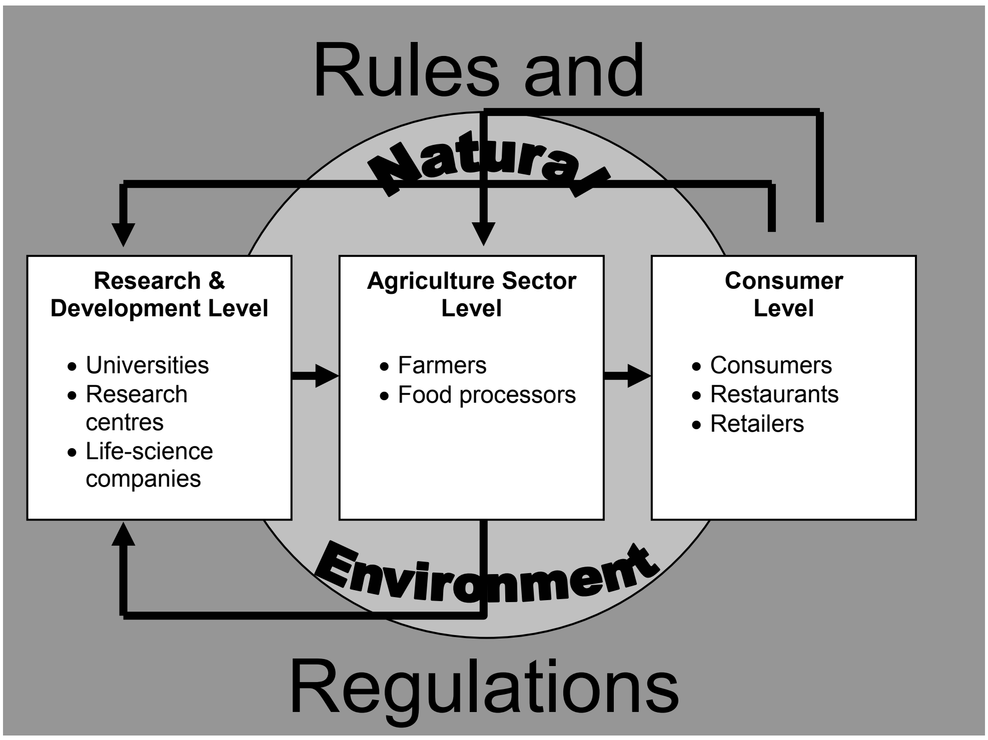

Figure 1. The transgenic-crop development chain

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This linear model of technology development ignores important feedback mechanisms. In reality, consumers send signals about their food preferences back to the farm sector and the farm sector sends them back to the technology provider. Additionally, within each box exchange of information between agents in the chain influences whether and how a new transgenic crop and derived food products will be successfully introduced and, hence, influences their environmental impact.

The rules and regulations that national governments and international organizations use to govern the release of transgenic crops also influence the behaviour of agents within the chain and, consequently, the environmental impact. Those rules and regulations do not appear out of the blue; in fact they are made by humans who act in their own interest. The political economy of deciding about rules and regulations adds another dimension of complexity.

Considering the interactions between the agents, the problem of identifying the economic costs and benefits of environmental impact from transgenic crops appears like the Gordian knot, a problem almost impossible to solve. This book takes a step towards trying to disentangle parts of the knot by examining specific aspects of environmental costs and benefits of transgenic crops from the points of view of the natural and social sciences.

From the various contributions in this book, a structure emerges that, while not yet complete, helps to understand the economic benefits and costs of environmental impact of transgenic crops.

The papers, written by natural and social scientists, cover both environmental and economic perspectives. They were presented at a workshop held in Wageningen in June 2003. The first nine chapters focus on the interaction between the natural environment and the economy at farm level. The last four chapters include the research and development perspective as well as a view from the consumer side. Each chapter in this book includes a comment by a workshop participant that raises issues discussed after the presentation.[1]

Ervin and Welsh start with an overview of the environmental costs and benefits of transgenic crops and then look at the current environmental regulatory process in the US. They argue in line with the National Research Council (NRC) and other researchers that more emphasis must be placed on controlling the type-II error (accepting a false negative, such as concluding that transgenic crops are environmentally safe, while in fact they are not) when analysing the environmental effects of transgenic crops within a risk-assessment framework. They further propose a differentiated environmental-risk assessment for transgenic crops that is based on the genetic difference of the transgene to the genes of the modified crop. They suggest three risk models for the five categories of genetic difference as discussed by Nielsen (2003). The first risk model would apply to crops that are produced by breeding processes that are close to the traditional (non-GM) ones. The ecological risk of those crops is assumed to be similar to the risk of crops produced by traditional methods. In this case the control of the type-I error (accepting the hypothesis of no negative impact on the environment when in fact it should be rejected) is sufficient. Examples are herbicide-tolerant crops. New crops that are produced with methods that go beyond what is possible with traditional breeding methods, such as insect-resistant crops, require a higher standard of ecological-risk assessment. The third category includes synthetic genes and novel proteins. As the genetic distance for this type of crops from those that are bred by traditional methods is greatest, the authors propose even stricter standards of tests. They suggest that tests should be carried out by experts who, in the case of wilful fraudulence will be held liable to avoid biased assessments. The risk assessment is then combined with a benefit-costs analysis that differs according to the category of crop under consideration. With the differentiated risk assessment the authors propose a case-by-case approach that goes beyond the current regulatory approach in the US and supports the view of the EU that the precautionary principle should be applied. The authors also suggest that a proper regulatory system can provide incentives for the private sector to develop transgenic crops with traits that provide ecological benefits of a public good nature. One eminent example would be a crop that is resistant rather than toxic to pests. Developments in this direction will provide a number of environmental benefits that may result in a reduced release of toxic substances.

Kleter and Kuiper address this particular topic in Chapter 3. Changes in pesticide use emerge as one of the most important impacts of transgenic crops on the environment. The measurement of the environmental impact of pesticide use is still not solved. One indicator is the Environmental Impact Quotient (EIQ) that includes impact of pesticides on the environment, on farm workers and on consumers. An application of the EIQ to herbicide-tolerant (HT) soybeans indicates an overall positive environmental impact of HT soybeans over non-HT soybeans. On the other hand, available indicators have several shortcomings addressed by the authors. The EIQ does not consider temporal aspects. Those can be important, e.g. for measuring the effect on water reservoirs of a continuous use of glyphosate on herbicide-tolerant crops. Long-term effects also pose problems for environmental-risk assessment, which should include an economic assessment as indicated in the previous chapter.

The paper by Laxminarayan and Simpson addresses the inter-temporal aspects of toxin-producing transgenic crops for pest management. They use a bio-economic model that combines a pest-population model with a social-welfare model. The resistance of pests to the toxin is modelled as a renewable resource that can be controlled by refuge areas. The social welfare depends on the net yield from agriculture and the amount of land used as a refuge area. The model is fairly simple and is introduced to illustrate possibilities for modelling transgenic crops. The contribution by Laxminarayan and Simpson indicates that in general a monopolistic technology provider may have incentives providing stacked varieties, but this will depend on the protection of IPRs, the market structure and the life-span of the single trait and stacked varieties. As Soregaroli points out in his comments on the paper, the model will become more complex if instead of insect pests weeds are considered.

A direct link from the previous chapter can be made to the contribution of Schubert, Matoušek and Supp in Chapter 5. The authors present results from research on virus-resistant potatoes and discuss the potential of private-sector investment for virus-resistant potato varieties. The private sector has low incentives to develop virus-resistant potato varieties as other traits like taste or colour are far more important. As virus-resistant potatoes can lead to reduced pesticide use, which provides a public benefit, public-sector research in that area can be justified. The net benefits of this research depend on the research costs, which can increase significantly with an increase in bio-safety regulation, and hence reduce potential public benefits. In addition, virus-resistant potatoes may require managed planting of potatoes to sustain the benefits from-virus resistant potatoes over several years. The paper illustrates two important problems for pest management as mentioned in the comments by Laxminarayan. First, potato viruses replicate fast and with a high mutation rate, overcoming the defence mechanism of the resistance gene, and second, wide use of the resistance gene can result in a more virulent strain of the virus. The comment again highlights the need for managed planting of the virus-resistant potato and the consideration of economic and biological factors for a successful development and application of the technology.

The importance of combined biological and economic assessment for transgenic crops directly leads to the contribution by Hurley in Chapter 6. The paper illustrates that the economic efficiency of the regulations for planting *Bt* corn in the US can be improved by considering the economic environment for planting *Bt* corn. If economists had been involved from the beginning in preparing the regulations, the economic efficiency of the adopted regulations could have been improved. The problem of expert panels appears again in the presentation by Hurley. It is also a good example of the need for interdisciplinarity in designing cost-effective regulatory policies.

Assessing the environmental costs and benefits of transgenic crops and designing appropriate regulatory systems is difficult, even if the potential implications are known. In Chapter 7 van de Wiel, Groot and den Nijs present the high variations of results in studies on gene flows, which make it difficult to get a consistent view about the implications for the environment. Regional aspects seem to be very important in quantifying the magnitude of gene flow. Scatasta stresses this point in her comment and asks whether the observed low risk of gene flow in the US would also be observable in Europe with its mosaic structure of fields.

Demont, Wesseler and Tollens in Chapter 8 demonstrate that those implications can be important. They discuss the difference between irreversibilities from a biological and economic point of view. While resistances of pests to the *Bt* toxin can be reversible from a biological perspective, occurrence of resistance will nevertheless result in irreversible costs. The economic implications of irreversible costs are explained using the case of transgenic sugar beets. The expected benefits for farmers are compared with environmental concerns of consumers. The results show that, if a household in Europe were willing to pay about 1,00 Euro per year for not having transgenic sugar beets introduced, based e.g. on concerns about the impact on biodiversity, this amount would from a social point of view justify not releasing transgenic sugar beets. As one Euro is a very small amount, this can justify the decision of the European Union not to release herbicide-tolerant sugar beets. Moreover, the results differ considerably by member state. In combination with regional differences in gene flow, there will be regions where the planting of transgenic crops will be more important from an environmental point of view. The regional differences are of relevance for Europe, as European agriculture is more heterogeneous than agriculture in the US and Canada. The importance of heterogeneity for the spatial adoption of transgenic crops is illustrated in the case study on ht-soybeans by Weaver in Chapter 9.

In Chapter 10 Gilligan, Claessen and van den Bosch provide further evidence about the spatial importance of planting transgenic crops. The theoretical framework they present allows consideration of the spatial and temporal dynamics of gene movements. By using the case of oilseed rape they show that stochastic models are far more important than deterministic models of gene movement. The resulting probability distributions about local persistence of novel genes provide important information for an environmental-risk assessment of transgenic crops. The model indicates the scope for reducing the environmental risk by introducing novel genes that are spatially explicit. This provides further support for regional management of transgenic crops.

Soregaroli and Wesseler further substantiate the importance of regional aspects in Chapter 11, where spatial implications of coexistence are analysed. The authors show

how *ex-ante* regulations and *ex-post* liability rules can effect the decision of a farmer to adopt transgenic crops and, importantly, that the choice of the regulatory system has an impact on adoption that will not be independent of the farm size. Decision-making bodies can influence the adoption rate by the governance rules for transgenic crops. While Soregaroli and Wesseler only analyse the adaptation to the regulatory framework within the farm, Beckmann in his comments adds another view that looks into the possibilities for co-operation among farmers. The possibility for co-operation results in a different cost structure that suggests the existence of a threshold between choosing a solution based on co-operation with neighbours and choosing a solution within the farm. These results again stress the importance of the regional impact for adoption of transgenic crops and consequently for environmental impacts as well.

The planting of transgenic crops and the environmental implications do not only depend on the decisions made at the farm level. There is a feedback to the upstream supply side, the R&D sector and a feedback from the downstream demand side. The private-sector incentives for developing technologies depend to a large extent on the regulatory framework. In Europe, the precautionary principle guides the decisions on the release of transgenic crops. Van den Belt provides an overview of the implications of a strong and weak interpretation of the principle and its implications for international trade, specifically the dispute between the US and the EU.

The discussion about different regulatory systems directly leads to the question of intellectual property rights (IPRs) and transgenic crops. Goeschl in Chapter 13 looks into the implications of different IPR systems for incentives to invest in environmentally friendly transgenic crops such as virus-resistant potatoes. The incentives will basically depend on the lifetime of the IPR-protected technology. The lifetime depends on the IPR system itself but also on the impact of environmental factors such as the build-up of pest resistance. In general, it cannot be concluded that the current IPR system unilaterally supports crop developments that harm the environment. However, the appearance of transgenic crops offers the opportunity to re-assess the existing IPR system. Further research is warranted before conclusions about superior systems can be drawn. Hogeveen and Michalopoulos in their comment provide a very critical view about IPRs in the context of transgenic crops and raise the ethical issues that are associated with patenting living organisms.

Graff, Roland-Holst and Zilberman discuss the implications of IPRs on the efficiency of research. IPRs limit the access of others to knowledge that is important for R&D. The authors present implications of different IPR systems for public and private-sector research priorities and suggest a clearinghouse for IPRs, where information on IPRs is traded. The authors show that a clearinghouse can increase the social benefits from modern biotechnology. De Wit provides a cautious view about the potential benefits from biotechnology. He argues that, in the end, competition will eat-up the windfall profits of early technology adopters and farmers will not be better off.

But, who in the end will benefit from the introduction of transgenic crops? Hobbs and Kerr in Chapter 15 build the link between consumers and technology adopters. They highlight the problem that without labelling – either voluntary or mandatory – consumers cannot identify GM food. In the case without labelling, consumers who prefer GM-free food will be worse off. In the case of labelling, markets can be segregated in GM and non-GM food and consumers can express their preferences by selective buying behaviour. Whether the welfare of consumers will be enhanced in the case of labelling depends on the additional segregation and labelling costs and consumer preferences for GM and non-GM food. Generalizations about gains are difficult to make and the impacts need to be analysed on a case-by-case basis as stressed in the comments by Scatasta.

The book ends with the major conclusions drawn from the contributions and research priorities for further investigation of the environmental costs and benefits from transgenic crops.

I hope that readers will enjoy the chapters in this volume with the same enthusiasm as they were discussed during the workshop. The interested audience can find further updates on the topic at: http://www.sls.wau.nl/enr/frontisworkshop/.

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[1] The terminology within this book is in line with the glossary published by the Zaid et al. (2001).