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ECONOMIC IMPACT OF AGRICULTURAL BIOTECHNOLOGY IN THE EU: THE EUWAB-PROJECT

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EUWAB-Project (European Union Welfare effects of Agricultural Biotechnology), Project VIB/TA-OP/98-07**:** "Micro- and Macro-economic Analysis of the Economic Benefits and Costs of Biotechnology Applications in EU Agriculture - Calculation of the Effects on Producers, Consumers and Governments and Development of a Simulation Model"

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The EUWAB-project (European Union Welfare Effects of Agricultural Biotechnology)

Since 1995, genetically modified organisms have been introduced commercially into US agriculture. These innovations are developed and commercialised by a handful of vertically coordinated "life science" firms who have fundamentally altered the structure of the seed industry. Enforcement of intellectual property rights for biological innovations has been the major incentive for a concentration tendency in the upstream sector. Due to their monopoly power, these firms are capable of charging a "monopoly rent", extracting a part of the total social welfare. In the US, the first *ex post* welfare studies reveal that farmers and input suppliers are receiving the largest part of the benefits. However, up to now no parallel *ex ante* study has been published for the European Union. Hence, the EUWAB-project (European Union Welfare effects of Agricultural Biotechnology) aims at calculating the total benefits of selected agbiotech innovations in the EU and their distribution among member countries, producers, processors, consumers, input suppliers and government. This project (VIB/TA-OP/98-07) is financed by the VIB - Flanders Interuniversitary Institute for Biotechnology, in the framework of its Technology Assessment Programme. VIB is an autonomous biotech research institute, founded in 1995 by the Government of Flanders. It combines 9 university departments and 5 associated laboratories. More than 750 researchers and technicians are active within various areas of biotech research. VIB has three major objectives: to perform high quality research, to validate research results and technology and to stimulate a well-structured social dialogue on biotechnology. Address: VIB vzw, Rijvisschestraat 120, B-9052 Gent, Belgium, tel: +32 9 244 66 11, fax: +32 9 244 66 10, www.vib.be

Introduction

Since 1995, genetically modified organisms (GMOs) have been introduced commercially into US agriculture. These innovations are developed and commercialised by a handful of vertically coordinated "life science" firms who have fundamentally altered the structure of the seed industry. Enforcement of intellectual property rights (IPRs) for biological innovations has been the major incentive for a concentration tendency in the upstream sector. On the one hand, this monopolisation may increase long-run social welfare through an increased rate of investment in R&D. On the other hand, due to their monopoly power, these firms are capable of charging a "monopoly rent", extracting a part of the total social welfare. A popular argument used by the opponents of agricultural biotechnology (agbiotech) is the idea of an input industry extracting all benefits generated by these innovations. Are life science firms able to appropriate all benefits or is there a limit to their monopoly power? In the US, the first *ex post* welfare studies reveal that farmers are receiving the largest part of the benefits followed by the gene developers who receive the next largest share. However, up to now no parallel *ex ante* study has been published for the European Union (EU). Hence, the EUWAB-project (European Union Welfare effects of Agricultural Biotechnology) aims at calculating the total benefits of selected agbiotech innovations in the EU and their distribution among member countries, producers, consumers, input suppliers and government.

Are the First Wave Agbiotech Innovations Different from Previous Agricultural Innovations?

In the literature, two waves of agbiotech innovations are distinguished. The first wave, currently being commercialised mainly in the US, is based on *input* or *agronomic traits* (insect, herbicide and virus resistance, drought tolerance, etc.). The second wave covers *output* or *quality traits* (modified composition, nutraceuticals, new products, etc.). Using a historical framework, Demont and Tollens (1999, 2000) show that the specific features of the first wave are entirely coherent within the paradigm of the *second agricultural revolution* of Modern Times. At the end of the 19th and the beginning of the 20th Centuries, industry produced new means of transport and new agricultural equipment, bringing agriculture to its first world crisis of over-production in the 1890s. The second agricultural revolution extends this first phase of mechanisation up to the 20th Century, hinging on the development of new means of agricultural production issued from the *second industrial revolution*. In a continuous process, biologic innovations substitute for complete chemical innovations. Finally, through multi-market exploitation, chemical companies develop biotechnology that increases dependence on chemicals, whereas non-chemical companies tend toward developing biotechnology that substitutes for chemicals. Hence, first wave agbiotech can be seen as a simple continuation of the second agricultural revolution model.

Framework for Analysing Welfare Effects of Agbiotech Innovations

Only by diffusion and on-farm adoption can agricultural innovations pass on benefits to society. Figure 1 represents the agbiotech diffusion chain. Government can influence the speed, extent and benefits of adoption through five policy instruments: research expenditures, IPR legislation, regulatory approval, labelling policy and trade regulation. Several factors influence government policy decisions: geography, history, religious and socio-cultural aspects, political ideology, and national and international institutional context. However, action and information flows (dashed lines) from activists, lobby groups, media and consumers have proven to be important in influencing government decisions, especially in the EU.

The upstream sector of input suppliers covers a whole set of actors: public national agricultural research systems (universities and institutes), international agricultural research centres (e.g. the CGIAR) and private biotechnology companies. The structure of this sector (perfect versus imperfect competition or monopoly) determines price and purchase conditions of agricultural inputs and, indirectly, profitability of the farm sector. Lapan and Moschini (2000) show that, even in the case of imperfect competition (e.g. the agbiotech industry), the input supplier is not able to charge the maximum monopoly price due to the fact that the price of alternative, competing technologies (chemicals) is altered by adoption of the innovation. Declining pesticide prices turn conventional technologies attractive again. As a result, first wave agbiotech innovations generate some benefits and costs at the farm level, as has been demonstrated by numerous micro-economic *ex post* studies in the US. These effects flow from farmers to consumers to an extent that depends on the market structure of the intermediate marketing sector (processors, distribution, retailers, and so forth). In

the long run, profitability of the innovated technology depends on the structural characteristics of the agricultural commodity market (supply and demand response due to price changes, measured by *supply* and *demand elasticities*) as well as exogenous parameters (government policy, trade, economic growth, income, etc.).

In conclusion, Figure 1 shows that a total system approach is required in order to assess total benefits and costs of agbiotech innovations. Consumers (food safety, the "right to know") and environment (benefits and risks) play a crucial role in this assessment. Secondly, it's clear that a case-by-case approach is essential to isolate specific agronomic and market features of commodities from their agbiotech economics.

Simulation Model for Analysing Macro-economic Impact of Agbiotech Innovations

In a first stage, an extensive literature review has been conducted on the economics of technological change in general and, more specifically, on the economics of agricultural biotechnology innovations. As a result, a comprehensive database containing the references of more than 1300 economic articles is available from the authors upon request. In a second stage, a simulation model has been developed to assess the impact of agbiotech innovations on the economic actors of the agricultural technology diffusion process. We describe some general features of this model as well as its major differences compared with conventional models.

Let $S_0(p)$ be the upward sloping supply curve and $D(p)$ the downward sloping demand curve for the conventional agricultural commodity being modelled (Figure 2a). The agbiotech innovation is assumed to be cost reducing. Cost reduction means that for

the same quantity y produced, the farmer is willing to accept a lower price and for the same price p, he is prepared to supply a higher quantity y. Hence, cost-reducing agricultural innovations can be modelled as technical change resulting in a shift of the supply curve from $S_0(p)$ to $S_1(p)$. This supply shift leads to an increase in economic welfare, equal to the area *ABCD*, the so-called *gross annual research benefits* (GARB). The model presented in Figure 2a has been used for numerous agricultural research evaluation and research priority studies (Alston, Norton, and Pardey, 1995). However, since IPR-protected firms have developed most of the recent agbiotech innovations, prices for these products are higher than they would be in a perfectly competitive market. Therefore, Moschini and Lapan (ML) (1997) bring along some new elements in the conventional analytical framework of welfare economics. They complete the framework by including the possibility that the innovation is protected by IPRs in the input market. Thus, the correct evaluation of the benefits from R&D aimed at agriculture needs to account for the relevant institutional and industry structures responsible for the actual development of technological innovations.

Let $X(w)$ be the downward sloping demand curve of the farm sector for genetically engineered seed (Figure 2b). The higher the price w, the lower demand x will be for the improved variety due to the existence of alternative conventional technologies such as chemicals. Once the R&D costs of the agbiotech firm are sunk, the firm is able to supply seed at a marginal cost c. This is the cost of producing an additional unit of genetically engineered seed and is equal to the marginal cost of producing conventional non-GM seed. In a perfectly competitive market, the GM seed price would approximate this marginal cost due to a continuous process of price competition. However, the IPRs allow the firm to hold a temporary monopoly

position, bounded of course by some limit pointed out by Lapan and Moschini (2000). If the firm is the only player in the market, it faces the downward sloping demand curve for GM seed $X(w)$. The marginal return curve MR, or return of an additional unit seed sold on the market, can be easily derived from this demand curve (Figure 2b). The firm will maximize profits by producing an amount GM seed equal to x_m, where marginal cost c is equal to marginal return MR. Since it is the only player in the market facing demand curve $X(w)$, the firm is able to raise its price above the marginal cost c. Even at a price w_m, the farm sector is willing to buy x_m units of the GM seed variety. This *monopoly price* w_m will maximize firm profits and will allow the firm to regain the high R&D costs via a so-called *monopoly rent*, represented by area cw_mEF. Total welfare increase will be equal to the sum of area $ABCD$ and area cw_mEF, instead of simply area $ABCD$ as in the conventional model of Alston, Norton and Pardey (1995).

Until now, few studies have been published calculating the welfare effects of agbiotech innovations using the ML-model. They are applied on typical US export crops like Bt cotton (Falck-Zepeda, Traxler, and Nelson, 2000) and RR© soybeans (Moschini, Lapan, and Sobolevsky, 2000). The major difference with the EU is the fact that these American studies regard an *ex post* setting, while the recent moratoriums on GMOs in the EU and the absence of empirical farm level impact data oblige us to use *ex ante* assumptions about yield increases, cost reductions and technology fees. However, this limitation makes it particularly interesting, because studying the *potential* welfare effects associated with agbiotech in the EU reveals the *benefits foregone* or costs of a complete ban of GMOs in the EU. Secondly, the actual situation of consumer and environmental concerns regarding GMOs in the EU

advances the challenge of completing the conventional models by including policy instruments like moratoriums, labelling regimes and identity preservation (separation of markets), consumer refusal (negative demand shifts) and environmental externalities (decrease in pesticide use, environmental risk). So far, no complete rational cost-benefit analysis has been carried out for the EU. Thirdly, the specific institutional features and market interventions of the EU reshape the model and its expected outcome profoundly. These are the features of the macro-economic simulation model:

- Partial equilibrium model: only one commodity at a time is modelled;
- Large or small open-economy depending on the commodity modelled;
- Two-region model: the EU and the "Rest Of the World" (ROW);
- Technology spillovers included;
- Monopoly rents of input suppliers included;
- Parallel supply shift induced by the agbiotech innovation;
- Short- as well as long-term analysis;
- Non-spatial: intra-EU trade flows are not modelled;
- Disaggregated supply: since institutional pricing differs among member nations, supply of each separate EU member country is modelled allowing for a more rigorous analysis;
- Aggregated EU demand: since the model is non-spatial, only aggregate EU demand is taken into account, linked to a world model;
- Stochastic sensitivity analysis: via subjective prior distributions of non-deterministic parameters (elasticities, yield increases, cost reductions, etc.), stochastic simulation methods are used to generate posterior distributions of the outcomes of the model.

Selection of Relevant Case Studies

We mentioned the importance of a case-by-case approach. The selection of relevant case studies is crucial to obtaining a conclusive image about the potential welfare effects of agbiotech innovations in the EU. However, this selection is heavily determined by the availability of farm budget data and field trial results. Therefore, we limit our selection to the set of first wave agbiotech innovations currently available. Secondly, we try to diversify our selection by including different technologies (herbicide and insecticide resistance), crop uses (animal feed, industrial use and human consumption), crop trades (domestic and export), market interventions (highly subsidised and free market crops) and beneficiaries (northern and southern countries). The following commodities have been taken into consideration:

- Herbicide resistant (HR) sugarbeets: sugar is one of the most heavily traded and highly subsidised commodities of the EU by a very specific quota system. The EU is the world's largest exporter of sugar. Interesting about this case study is the fact that sugarbeets are more or less important for most EU countries;
- Insect resistant (IR), HR grain maize and "stacked" varieties, containing the two genes (IR and HR): the EU is self-sufficient in the production of maize, which is traded domestically and mainly used for animal feed and some industrial use and human consumption. France, Italy, Spain and Germany are the largest producers;
- IR and HR cotton: cotton production is important for some poor rural societies in southern Europe (Greece and Spain). The importance of profitability enhancing technologies in this heavily subsidised crop has been stressed by several authors;

- IR and HR potatoes: this is the only "free market crop" of the considered case studies, i.e. not subject to a EU market organisation. Potatoes are produced and traded domestically and used for human consumption, processing and animal feed. Like sugarbeets, potatoes are produced in the majority of EU countries;
- HR rapeseed: in recent years, the EU has become increasingly self-sufficient in the supply of this crop. Germany, France and the UK are the major players;
- rBST in milk production: the EU is a major player in the world market for milk and milk products with the majority of EU countries contributing to this.

Collection and Estimation of Parameters and Running of the Simulation Model for the Selected Case Studies

Structural parameters for the simulation model, such as supply, demand, export supply, export demand and income elasticities are taken from previously published studies. Production, consumption and trade data come from various statistical sources like Eurostat, USDA, European Commission, etc. The most crucial parameter of the simulation model is the supply shift or *K-factor*, which is a combination of the yield-increasing and cost-reducing effect of the technology and its technology fee. The estimation of the K-factor requires detailed total farm budgets for a representative sample of farms in all member countries of the EU. However, disaggregated farm budgets displaying herbicide costs, weeding costs (labour and equipment) and insecticide costs (scouting, application, equipment) are difficult to obtain for all countries. Generally, national Farm Accountancy Data Network (FADN) data are highly aggregated, adding up all pesticide costs for all crops into a single cost entry "plant protection products". Nevertheless, using these data as a benchmark, we can combine and complete them with a variety of sources like field trial results, expert

opinions and assumptions, published studies, surveys, etc. These data will provide us a reliable estimate of the K-factor as well as indications about its subjective prior distribution, which can be used in stochastic sensitivity simulations to generate posterior distributions of the size and distribution of the benefits of agbiotech innovations in EU agriculture.

Conclusions

It's clear that, in order to make an *ex ante* assessment of the economic benefits and costs of agbiotech applications in the EU, detailed total farm budgets reflecting the real production costs of farmers are needed for different countries or regions in the EU. These data will allow us to calculate average farm level cost reductions and yield increases associated with these innovations. To illustrate the level of detail required to assess the farm-level costs en benefits of biotechnology, table 1 represents a farm budget of an "average" sugarbeet grower in the UK. The data have been collected via the survey "Crop Profitability Initiative" (CPI) on a sample of 300 sugarbeet growers, organized by British Sugar (Limb, 2000). In the case of sugarbeets, the most crucial point is the total cost spent on the weeding operation (herbicides, tractor hoeing and chemical application costs). In the case of Bt corn, this would be the insecticide costs plus scouting and applications costs. However, since the percentage change in total costs have to be calculated, total farm budgets are needed. If sufficient data is available, it could be interesting to obtain such a budget for each region in the EU, or even for different yield groups or quota groups of farms. In that case, we will be able to analyse how the costs and benefits of biotechnology innovations will be distributed among different regions and producer groups.

Table 1: Total Farm Budget of an Average Sugarbeet Grower in the UK

Category		CPI 300 Average
	Adjusted Yield (t/ha)	59,70
	Average Beet Price (£/t)	25,96
Total Output		1549,76
Variable Costs (£/ha)	Seed	99,11
	Fertiliser	89,40
	Organic Manure/Lime	16,33
	Herbicides	**115,70**
	Insecticides	36,29
	Fungicides	7,75
	Foliar Feeds	4,84
Total Variable Costs (£/ha)		369,42
Gross Margin (£/ha)		1180,34
Operational Costs (£/ha)	Primary Cultivations	40,16
	Other Cultivations	25,63
	Drilling	27,96
	Fertiliser Applications	16,90
	Chemical Applications	**33,78**
	Tractor Hoeing	**10,64**
	Irrigation	6,06
	Other	5,59
	Harvesting	149,25
	Delivery	238,57
Total Operational Costs (£/ha)		554,53
Other Overheads (£/ha)		100,00
Total Costs (£/ha)		1023,95
Unit Cost (£/ha)		17,15
Enterprise Margin (£/ha)		525,80

Source: Limb (2000)

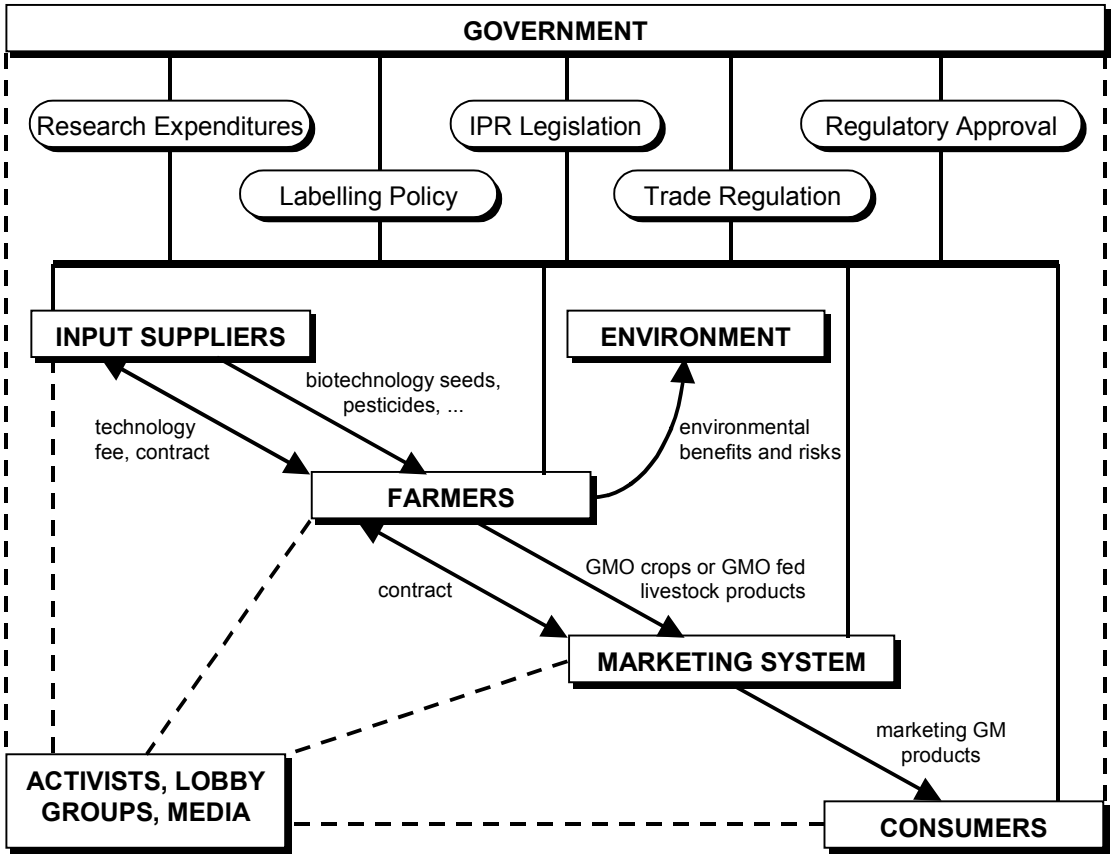

Figure 1 : Simplified Representation of the Multi-stage Agbiotech Diffusion Chain

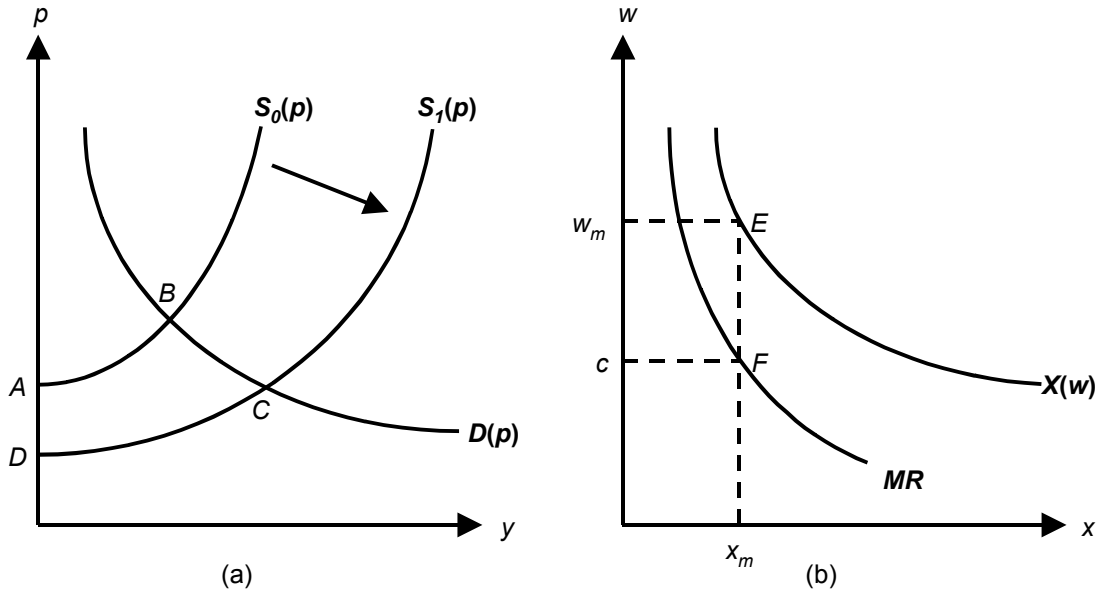

Figure 2 : Gross Annual Research Benefits (area ABCD) and Monopoly Rents (area cwmEF) Resulting from an Agbiotech Innovation

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