**Katholieke Universiteit Leuven**
**Faculty of Agricultural and Applied Biological Sciences**

Working Paper
2001 / 57

# RESHAPING THE CONVENTIONAL WELFARE ECONOMICS FRAMEWORK FOR ESTIMATING THE ECONOMIC IMPACT OF AGRICULTURAL BIOTECHNOLOGY IN THE EUROPEAN UNION

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March 2001

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”

Financial support of the VIB – Flanders Interuniversitary Institute for Biotechnology is gratefully acknowledged.

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Demont, M., and E. Tollens. "Reshaping the Conventional Welfare Economics Framework for Estimating the Economic Impact of Agricultural Biotechnology in the European Union." Working Paper, n° 57, Department of Agricultural and Environmental Economics, Katholieke Universiteit Leuven, 2001.

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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

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## Abstract

Some of the crucial assumptions of applied welfare economics do not hold any longer in the case of agricultural biotechnology innovations. We review some modifications to the conventional methodologies measuring the size and distribution of agricultural research benefits, which are critical for the assessment of the economic impact of agricultural biotechnology in the European Union. While some modifications are related to the specific features of modern agricultural biotechnology and technology adoption, others are related to the specific institutional settings of the European Union's Common Agricultural Policy and commodity markets.

## Introduction

Already in the mid eighties, a decade before the adoption of the current wave of agricultural biotechnology innovations, Fishel (1985) expressed concern about the adequacy of conventional analytical techniques to examine the impact of modern agricultural biotechnology. He even advanced the need to reexamine the philosophical conceptualisation about how technology assessment studies of biotechnology are considered and contends that there must be some analytical extensions to these methodologies in order to generate the kind of information that is going to be required by decision and policy makers.

Beginning with the early contribution of Griliches (1957), an extensive literature has developed about the measurement of the size and distribution of agricultural research benefits. This literature has been reviewed and summarized by Alston et al. (1995). At the centre of this literature is a partial equilibrium market model for a commodity, with competition in both factor and product markets. A research-induced technical change is modelled as a shift of the commodity supply function, and Marshallian producer and consumer surplus measures are used to evaluate the welfare consequences of the given supply shift.

However, developments in the market structures of the up- and downstream sectors surrounding the farm sector, cast doubts on some crucial assumptions of this modelling approach. As a result, the modelling framework has been continuously reshaped, adapted and completed. While some modifications are related to the specific features of modern agricultural biotechnology, others are related to the institutional settings of the European Union's Common Agricultural Policy (CAP).

Only by diffusion and on-farm adoption can agricultural innovations pass on benefits to society. Figure 1 represents the agbiotech diffusion chain, to which we will refer throughout the paper. 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. 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 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.

## Imperfect Competition in the Output Market

While the implications in a competitive market setting are now well known, relatively little work has been done on the effects on research benefits of distortions arising from imperfect competition in markets for agricultural commodities (downstream marketing system in Figure 1). The limited existent literature indicates that imperfect competition could have significant effects on the size and distribution of research benefits. However, most of this literature has assumed extreme forms of imperfect competition (monopoly or monopsony) that seem at least as inappropriate as one of perfect competition.

Alston et al. (1997) propose a model that allows for more realistic representations of oligopsony or oligopoly behaviour in the processing industry and a parameterisation of such a model that gives some indication of the quantitative effects on research benefits of given departures from perfect competition. They study the effects on the magnitude and distribution of research benefits of a wide range of degrees of oligopsony power of processing firms in buying raw farm products and oligopoly power in selling processed farm products. The authors conclude that a competitive processing sector operating under constant returns to scale captures none of the research benefits. However, firms with market power will restrict the output expansion, caused by technological change, relative to what it would be under perfect competition (creating an artificial scarcity), which will increase the deadweight loss from market power. This increase in deadweight loss represents the benefits from the innovations that are foregone due to imperfect competition in the marketing sector. Research benefits under imperfect competition will be equal to the corresponding benefits under competition minus any increase in the deadweight loss associated with market power caused by the research-induced supply shift. This deadweight loss is determined jointly by the degree of monopoly (monopsony) and by the elasticity of the demand (supply) function. As market demand becomes more inelastic relative to market supply, the processors' share in the total benefits will increase if processors' market power is relatively greater in the output market, enabling them to better exploit the relative inelasticity of demand. Farmers are made worse off by an increase in processor oligopoly power because the incremental output contraction it implies will also diminish demand for their raw product. Similarly, consumers' welfare is also diminished by an increase in the extent of either oligopoly or oligopsony power.

Since concentration in the marketing sector is very common in the European agribusiness chain, agbiotech impact studies have to take into account the possibility that this sector diminishes total benefits and extracts a part of them, at the expense of other agents in the agbiotech diffusion chain: producers, consumers and input suppliers (Figure 1). Up to now, the only contribution incorporating the assumption of imperfectly competitive markets in their agbiotech impact analysis is the recent study of Nadolnyak and Sheldon (2001). Their paper models the distributional effects of partial adoption of genetically modified soybeans under the assumption of imperfect competition in the soybean processing market. In doing so, the authors show the welfare costs of market imperfections due to the fact that market power slows the adoption process, but maintains a higher level of traditional soybean production. Thus, for our case studies it is important to study the market structure of the downstream sector in order to identify the existence and degree of market power which influences the size and distribution of the research benefits due to the adoption of agbiotech.

## Imperfect Competition in the Input Market

While relatively little work has been done on imperfect competition in the output market (cfr. supra), no work at all existed on imperfect competition in the input market until 1997. Before, research benefits were estimated assuming that the research is publicly funded and competitively sold in the input market. Figure 2 represents (a) the output and (b) input markets surrounding the farm sector. Let $S_0(p)$ be the upward sloping supply curve and $D(p)$ the downward sloping demand curve in the output market 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 $S_c(p)$ on the condition that the innovated input is competitively supplied. This supply shift leads to an increase in economic welfare, equal to the area *ABDE*, 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 et al., 1995). However, most of the recent agbiotech innovations have been developed by private firms protected by intellectual property rights (IPR), such as patents, which confer monopoly rights to the discoverer (with some limitations). This is a new phenomenon in the agribusiness sector. The result is that prices for these inputs 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 in the input market (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 $w_mGHc$. Because of the fact that the monopolistic seed price $w_m$ is higher than the marginal cost $c$, i.e. the seed price which would emerge in a perfectly competitive market, farm-level benefits are lower and the corresponding supply shift is smaller (from $S_0(p)$ to $S_m(p)$). The effects of a departure from the assumption of perfect competition towards monopoly are illustrated in Figure 2 by a shift of the supply curve from $S_c(p)$ to $S_m(p)$. Total welfare increase will be equal to the sum of the shaded areas $ABCF$ and $w_mGHc$, instead of simply area $ABDE$ as in the conventional model of Alston et al. (1995). A part of the producer benefits ($ABDE$ - $ABCF$) will flow to the input sector in the form of monopoly rents ($w_mGHc$). Until now, few studies have been published calculating the impact of agbiotech with the ML-model. They are applied on typical USA export crops like Bt cotton (Falck-Zepeda et al., 2000) and RR© soybeans (Moschini et al., 2000).

However, equivalently with what Alston et al. (1997) pointed out in their study, extreme assumptions of monopoly or monopsony seem at least as inappropriate as one of perfect competition. Indeed, different patents exist for the same phenotypic trait, e.g. RR® (Monsanto) and LL® (Aventis) for herbicide resistance. Thus, the ML-model, which focuses on the extreme setting of pure monopoly, might need to be adapted to account for a departure from monopoly to different oligopolistic settings. This can be visually done in Figure 2b by rotating the marginal return (*MR*) curve towards the demand curve ($X(w)$) in the input market (Fulton and Keyowski, 2000). If the *MR* curve in Figure 2b corresponds to the extreme position of monopoly in the input market, in the case of pure competition this curve would coincide with the $X(w)$ curve. An oligopolistic input market would then be an intermediary situation between these two extremes, with a marginal return curve situated somewhere between *MR* and $X(w)$. In Figure 2a, a departure from monopolistic towards oligopolistic input markets can be visualized by shifting the supply curve from $S_m(p)$ to somewhere between $S_m(p)$ and $S_c(p)$.

## Market Distortions Caused by Commodity Policies

The benefits from agricultural research can be influenced by government policies that distort output and input prices. Several studies have examined the research benefits under a variety of output pricing and other government policies. The major findings from these studies are summarized in Alston et al. (1995). The latter reshape the modelling framework for five market distortions caused by government intervention policies: (1) price supports, (2) output price ceilings, (3) subsidies on inputs or outputs, (4) output controls (quota systems), (4) import tariffs and import quotas and (5) export taxes.

Since some of these government interventions are embedded in the Common Agricultural Policy (CAP) of the EU, case studies evaluating the benefits of new technologies in the production of a particular commodity have to take into account the relevant institutional policies which interfere in the commodity market. To illustrate the influence of distorting market policies on the size and distribution of research benefits, Figure 3 represents the quota system of the European common sugar market. This Common Market Organisation (CMO) is central in the case study of herbicide tolerant sugar beets. The quota system is in place since the establishment of the CAP for sugar in 1968. Each year the EU fixes an intervention price $P_i$ from which it deduces the price levels of A-quota ($P_a$) and B-quota ($P_b$). To each country an amount of A-quota ($Q_a$) and B-quota ($Q_b$) is allocated. Historically, anticipating an increase in consumption, these quotas have been fixed at a level, which is superior to domestic demand $Q_d$ (Combette et al., 1997), the quantity demanded at a price $P_i$, defined by the intersection of the demand curve (*D*) with the fixed intervention price $P_i$. The production of C-sugar is not limited but it receives the world price ($P_w$), without price support. Now consider two producing countries, characterized with supply or marginal cost functions $S_0$ and $S'_0$. The marginal return curve (*abcdef*) is stepwise with a discontinuity at b and d. $S_0$ represents a high cost producer since it fulfils its A- and B-quota (his marginal cost curve $S_0$ intersects with the marginal return curve at $Q_a + Q_b$), but is too expensive to produce any C-quota ($P_w$ is lower than the intersection of marginal cost and return). $S'_0$ is the marginal cost curve of a low cost producer, who is able to supply an amount of unsubsidised C-sugar ($Q_c$), after fulfilment of his A- and B-quota.

Now, consider a technological innovation represented by a parallel shift of the supply curve (from $S_0$ to $S_1$) by an absolute cost reduction of $K$ (in Euro/tonne). The total producer benefits of this innovation are $K(Q_a + Q_b)$, visualized by the shaded rectangle. Since prices and quota are fixed, no direct price effect will occur on the domestic market as a consequence of the technological innovation. In a free market, increased supply due to the innovation would result in lower prices if the farm sector faces an inelastic demand. Therefore, within quota production is entirely protected from any price depreciation due to a technological change. The producers (farmers and processors) capture the full benefits in the output market, while no benefits flow to consumers. A low cost producer ($S'_0$) will gain a 'protected' quota rent increase $K'(Q_a + Q_b)$ from his A- and B-quota sugar, equivalent to high cost producers. Moreover, he will capture an extra benefit on the export market originating from his

C-sugar. This benefit, however, is not protected from price depreciation, so it will be less than $K'Q_c$. From this example it becomes apparent that the specific institutional policies intervening in the commodity market shape profoundly the model. An important conclusion is that there will not exist a unique simulation model for all agbiotech case studies, since it has to be adapted to the specific features of the Common Market Organisation (CMO) of each commodity being modelled.

## Producer Heterogeneity

The argument that producers benefit if the cost of growing crops falls by adopting their alternative GM varieties depends critically on the belief that all farmers are identical in the agronomic factors they face, the management skills they possess, and the other technology they have adopted. If farmers are different in these characteristics, no such easy test of producer benefit is available. Moschini and Lapan (1997) show that privately funded R&D provides benefits to the farmers if the innovation resulting from R&D is drastic[1]. All things equal, the more concentrated is the seed and chemical industry, the more likely are seed prices and chemical prices to be raised to the point where an innovation becomes non-drastic (cfr. supra). The notion of a drastic innovation is only relevant if all producers of the crop face the same costs and agronomic factors.

Fulton and Keyowski (2000) provide some empirical evidence that the adoption of herbicide resistant canola[2] by Canadian farmers is best understood if the assumption that farmers are identical is relaxed and replaced with the assumption that they differ in terms of such characteristics as management ability, geographical location, age, education, farm size, product specialization and the degree to which they have adopted conservation tillage methods. Contradictorily, in spite of the fact that average production costs of the GM canola varieties were higher (due to lower[3] yields) than their conventional counterparts, adoption of these varieties has been very fast (from 4 % of the total canola acreage in 1996 to 69 % in 1999). Parallel to these observations, European field trials reveal analogous inconsistencies for transgenic oilseed rape, showing that net benefits only occur in areas of high weed pressure, in fields were problem weeds such as cleavers and poppies are difficult to control with conventional treatments and in fields with low soil moisture and high organic matter (Green and Booth, 1999; Booth et al., 2001). The same inconsistencies have previously been reported in literature on the response of oilseed rape to herbicide use (Walker et al., 1990).

These data, however, are not contradictory if it is recognised that producers differ in certain respects. Fulton and Keyowski (1999; 2000) develop a conceptual model in which producers are differentiated in some respect. Their model shows that some producers benefit even if only a portion of the market switches to the new technology, i.e. the technology does not have to be drastic for there to be a producer benefit. Moreover, producers can benefit and a portion of producers will adopt the new technology, even when the latter appears to be priced higher than the old technology. Their methodology can provide an extension to the conventional welfare framework by refining producer benefits according to some differentiating factors in cases where average production budgets reflect that the innovation is non-drastic.

## Consumer Heterogeneity and Labelling Policies

Like the effect on farmers of agbiotech can only be understood if they are regarded as heterogeneous, the rise of consumer concerns over GM products suggests that also consumers are not homogenous but differ in their willingness to pay for GM versus non-GM products (Fulton and Keyowski, 2000). Consumer concern about genetically modified food is one of the most notable features of agricultural biotechnology. Unlike US farmers who have seen agronomic benefits in the new technology and have quickly adopted transgenic crops, consumers have expressed reservations about the foods produced from these crops. Consumer opposition to genetic modification started in Europe and has spread to other countries. While labelling of food products satisfies consumer demand for the right to make informed consumption decisions (Caswell and Mojduszka, 1996; Caswell, 1998), the introduction of segregation and labelling raises a number of issues that affect everyone in the food chain. One issue is the added costs that segregation and labelling introduce and the economic impact of these costs on consumers. Several recent studies try to shed light on these potential costs (Miranowski et al., 1999; Buckwell et al., 1999; Bullock et al., 2000; Lin, 2000; Golder et al., 2000). A second issue is that segregation and labelling activities create incentives for the misrepresentation and mislabelling of genetically modified food as traditional food.

Giannakas and Fulton (2000) develop a theoretical framework to examine the consumption effects of genetic modification under alternative labelling regimes and segregation enforcement scenarios. Their analysis shows that the relative welfare ranking of the “no labelling” and “mandatory labelling” regimes depends on: (1) the level of consumer aversion to genetic modification, (2) the size of marketing and segregation costs under mandatory labelling; (3) the share of the GM product to total production; and (4) the extent to which GM products are incorrectly labelled as non-GM products.

The results of their paper can provide an explanation of policy decisions about genetic modification and labelling observed around the world. Relatively low (or zero) consumer aversion to genetic engineering coupled with a reduced price of GM foods and significant segregation costs associated with mandatory labelling could be among the reasons why a “no labelling” policy has been adopted by countries like the United States and Canada. Increasing consumer concerns, however, and the relatively high level of consumer trust in the food safety institutions in both countries could increase the relative efficiency of – and hence the consumer demand for – mandatory labelling. A relatively high aversion to genetic modification coupled with a lack of consumer price reduction for GM foods, due to market distorting policies (cfr. supra), would rationalize mandatory labelling, an outcome seen in various EU countries. However, a high level of distrust of food safety and inspection systems can undermine the value of labelling. This result sheds light on the demand for an outright ban of GM products by some European consumers, since faith in the food inspection system there has been reduced because of food safety scares such as the BSE crisis in the British beef industry and the Belgian dioxin crisis.

But even in the case of mandatory labelling, the label itself can have an influence on the welfare effects associated with the labelling policy. Crespi and Marette (2000) develop an analytical framework showing that the label “Does Contain” should be used if the ration of consumers with a strong reluctance for consuming GMO goods to indifferent consumers is high, while the label “Does Not Contain” should be used if the ratio is low. Public intervention is crucial for GMO labelling because sellers may be unable, or unwilling, to signal their products on their own. The relevant variables for policy decisions, then, are not just the concerns of those citizens troubled by GMO goods, but also the ratio of reluctant buyers, as well as, the cost of labelling and who, ultimately, bears this cost.

Mandatory labelling policies imply market segregation and should be modelled as such. Desquilbet et al. (2000) provide a theoretical adaptation of the conventional welfare framework. They include mandatory labelling by splitting the commodity market into a regular (GM or non-GM) and an identity preserved (IP) non-GM market. In a first stage, they consider a hypothetic situation where consumers are indifferent between the attributes GM and non-GM (Figure 4). Selling agricultural commodities involves handling costs, presented in Figure 4a by two supply curves. $S_{rh}$ takes into account these handling costs, while for $S_r$ these costs are subtracted. Market equilibrium takes place at quantity $q_r = q_{rh}$ and price $p_{rh}$. The difference between $p_{rh}$ and $p_r$ are the handling costs. Identity preservation involves extra handling costs due to the need for keeping non-GM crops pure, testing and labelling under imperfect information. Hence, the distance between the two supply curves $S_{ih}$ and $S_i$ is greater in the identity preserved market than in the regular one. In the absence of GMO-reluctant consumers willing to pay a price premium for GMO-free commodities, no IP goods will be sold ($q_i = q_{ih} = 0$) unless prices are equal or lower than the equilibrium price in the regular commodity market. This explains the kinked shape of the demand function (fat line in Figure 4b).

In a second stage, new information about the potential risks of GM food differentiates the consumers in two groups: (1) consumers who do not care and (2) consumers who care. The emergence of a GMO-reluctant group of consumers with a higher willingness to pay for IP food creates a demand for the latter, pushing up the inelastic part of the demand function in the IP market (Figure 5b). If the handling costs of the IP system are not too high, market equilibrium can be reached and a non-zero quantity $q_i^1 = q_{ih}^1$ of the IP commodity is traded at price $p_{ih}^1$. The emergence of GMO-reluctant consumers leads to a negative demand shift (from $D_{rh}$ to $D_{rh}^1$) in the regular market resulting in lower prices ($p_{rh}^1$) and traded quantities ($q_r^1 = q_{rh}^1$):

| Regular Commodity Market: | Identity Preserved Commodity Market: |
|---|---|
| $q_r^1 = q_{rh}^1 < q_r = q_{rh}$ | $q_i^1 = q_{ih}^1 > q_i = q_{ih} = 0$ |
| $p_{rh}^1 < p_{rh}$ | $p_{ih}^1 > p_{ih}$ |
| $p_r^1 < p_r$ | $p_i^1 > p_i$ |

The result of this negative information diffusion of GM food is that consumers who do not care gain, due to lower prices of the regular commodity, while consumers who care loose, due to higher IP commodity prices. Farmers loose, whether they grow GM or non-GM crops and will switch to alternative crops resulting in a positive supply shift of the latter. GM gene and seed suppliers loose due to lower demand for their innovative inputs. Finally, these effects can be dampened to a certain extent by technological changes occurring in the IP system by lowering IP handling costs (Desquilbet et al., 2000).

Thus, in a situation with GMO's and identity preservation, the overall effect will depend on the relative importance of the supply shift due to technological change on the one hand, and the influence of negative information diffusion on the other hand. Whether farmers and consumers who do not care win, depends on the relative sizes of the supply shift due to technological change, the demand shift and the changes in handling costs for regular and IP commodities. Consumers who care loose in any case, due to higher prices[4]. The agricultural input suppliers finally win, but maybe not as much as in the hypothetical case of homogenous, indifferent consumers.

## Environmental and Human Health Externalities

There are many types of external effects in agriculture. An externality arises when there is a spillover effect of one person's actions on another person's economic opportunities and where that effect is not fully compensated trough a market transaction (Alston et al., 1995). Many people are concerned that the capacity of agricultural systems (globally of locally) is being depreciated too rapidly by excessive exploitation of the natural resource base. Underlying this concern is an implicit belief that agricultural decision makers are discounting the future too heavily, that they find it optimal to consume the natural resource base too quickly, compared with some standard. Two possible rationales are that (1) private discount rates are greater than social discount rates and (2) some individuals attach too little weight to the welfare of future generations. Thus, the costs of environmental externalities, perceived by society, are inseparably linked to the definition of a discount rate, which is representative for the society as a whole. The lower (higher) the discount rate, the more society attaches weight to the welfare of future (present) generations.

The decision-making rule for GMO's can be described as comparing – explicitly or implicitly – the expected costs of their release with the expected benefits. The release of the transgenic crop will be approved if the expected discounted sum of benefits exceeds the sum of the expected discounted costs. Traditional cost-benefit-analysis could result in socially non-optimal allocation of resources because the value of delaying a decision and waiting for additional information is neglected. Generally, the decision can be seen as one under temporal uncertainty and irreversibility. Real option pricing theory has shown that under such circumstances, the benefits have to exceed the costs by a factor significantly greater than one to account for the option to delay the decision. This factor is commonly called the hurdle rate (Wesseler, 2000).

Wesseler (2000) derives two different scenarios, which represent an optimistic and a pessimistic view on the effects of transgenic crops. The optimist assumes that transgenic crops will generate continuously but stochastic benefits. Using conservative *guesstimates* for the parameters of the hurdle rate, he shows that the hurdle rate has at least a factor of two. Under an optimistic view, additional benefits from transgenic crops should be at least two times the expected loss in biodiversity. The pessimist assumes that benefits, if at all, will be only available for a short period of time. Surprisingly, this model results in lower hurdle rates compared to the optimistic one, which could be explained by the higher value of the option to delay the decision due to the positive trend in additional benefits in the optimists model. The results further suggest that a tax on transgenic crops or mandatory refuge areas decrease the hurdle rate and therefore support an earlier release.

Capalbo and Antle (1989) observe that much research by economists is devoted to the measurement of the social benefits of agricultural research trough the adoption of agricultural technologies. Yet, little systematic effort was directed at the measurement of social costs caused by environmental damage and human health risk. The existing welfare economics framework has to be adapted to the valuation of externalities such as agricultural pollution. The authors propose a research sequence of (1) quantifying the physical and biological relationships; (2) quantifying the economic relationships; (3) quantifying the effects of the externalities on the environment and human health; (4) valuing the market and nonmarket effects; and (5) conducting benefit-cost analysis incorporating information on the social valuation of market and nonmarket effects. The paucity of data is a serious limitation to undertaking this research. Moreover, the nature of the physical and biological relationships evolves over time as the production technology changes. The time dependence of functional relationships causes the observed data to be nonstationary in the statistical sense. They conclude by saying that cross-disciplinary research is needed to measure the social costs of agricultural externalities when research priorities have to be set.

All of these issues, conceptually at least, can be considered in the framework of a conventional supply and demand model, allowing for a divergence between private and social costs or benefits from production. This is similar to incorporating price-distorting policies (cfr. supra) but different in that the distortions are not creations of governments (Alston et al., 1995). The authors represent this by adding a constant per unit cost to the marginal private cost (or ordinary supply) curve. This shifts the supply curve (now represented by the marginal social cost curve) to the left and means that, if not corrected for externalities, markets would be systematically oversupplied and exhibiting a continuously present externality cost. Thus, the effects of research-induced supply shifts have to be computed on producer surplus, consumer surplus, government revenues and those who bear the costs of externalities. Then the total benefit is obtained as the sum of benefits and costs to all groups.

In order to assess the total social costs of agbiotech innovations, reliable data about the potential positive (declining pesticide use, declining toxicity of pesticides) and negative externalities (gene flow risks, loss of biodiversity) of these technologies are needed, as well as – and this part is often neglected – data about the externalities of conventional and alternative technologies. Conventional agricultural systems rely often on toxic pesticides, which leach into groundwater. Even systems based on mechanical weeding rely on heavy machines compacting soils, enhancing soil erosion, consuming fuel and emitting exhausts in the atmosphere. Since conventional agricultural techniques are already associated with some externalities, the correct evaluation of the total social costs and benefits of agbiotech has to take into account them by computing the change in these costs when agriculture moves progressively from conventional to agbiotech techniques. If agbiotech applications in the EU are more environment-saving than conventional techniques, as they seem to promise, this would mean that the marginal social cost shift would be even greater than the marginal private cost shift and that net benefits (reduction of externality costs) are flowing to an important actor of the agbiotech diffusion chain: the environment.

## Conclusions

Fishel's (1985) concern about the adequacy of conventional analytical techniques to examine the impact of modern agricultural biotechnology was legitimate. Some of the crucial assumptions of applied welfare economics do not hold any longer in the case of agricultural biotechnology innovations. Therefore, we review some modifications to the conventional methodologies measuring the size and distribution of agricultural research benefits, shaping the conventional welfare economics framework to the specific case of agricultural biotechnology in the European Union.

First, some modifications are related to the specific features of commodity markets, like the existence of market power in the processing sector. A second set of revisions is associated with the characteristics of modern agricultural biotechnology: imperfect competition in the input market, consumer heterogeneity, and the risk of environmental and human health externalities. Thirdly, some modifications arise from the technology adoption process, like the incorporation of producer heterogeneity in adoption decisions. Finally, the specific institutional settings of the European Union's Common Agricultural Policy shape the model and its outcomes profoundly.

Any study aiming at assessing the size and distribution of the welfare effects of agricultural biotechnology in the European Union should take notice of these conceptual extensions to the conventional 'welfare economics' framework. But besides these modifications, also an extensive set of uncertainties has to be taken into account, reviewed in the next working paper (Demont and Tollens, 2001).

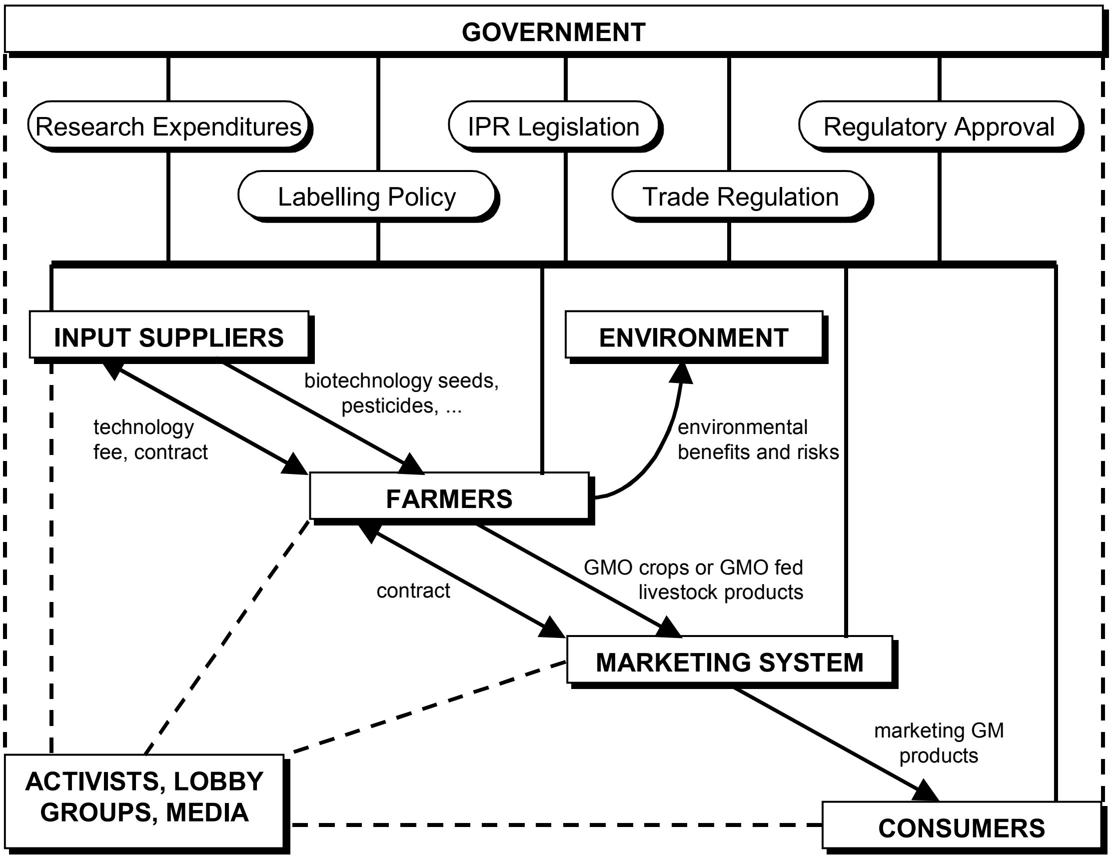


**Figure 1: Simplified Representation of the Multi-stage Agbiotech Diffusion Chain**

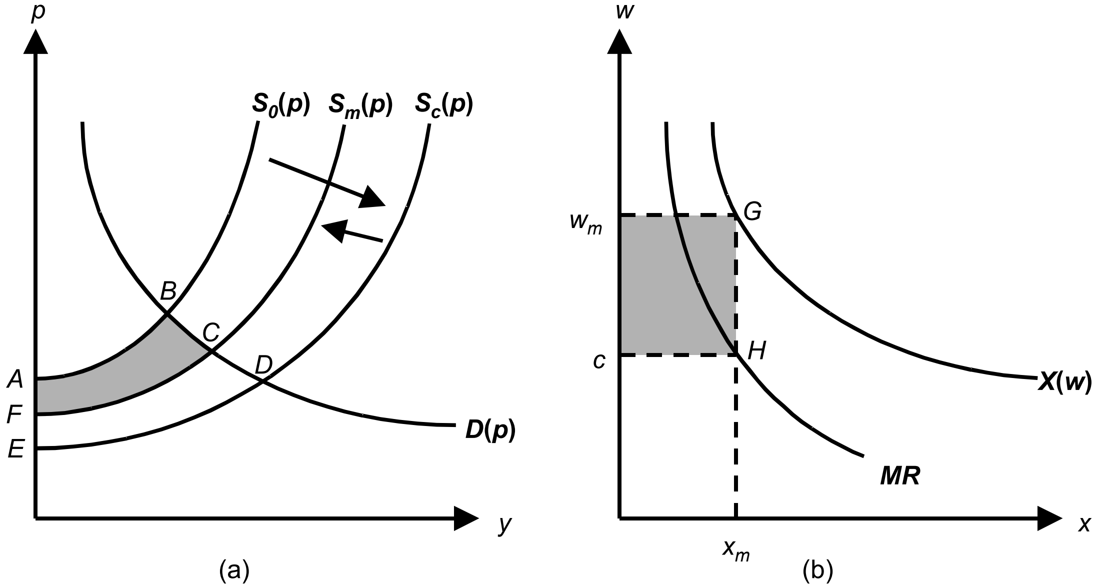


**Figure 2: Gross Annual Research Benefits (area *ABCF*) and Monopoly Rents (area $w_m GHc$) Resulting from an Agbiotech Innovation (Moschini and Lapan, 1997)**

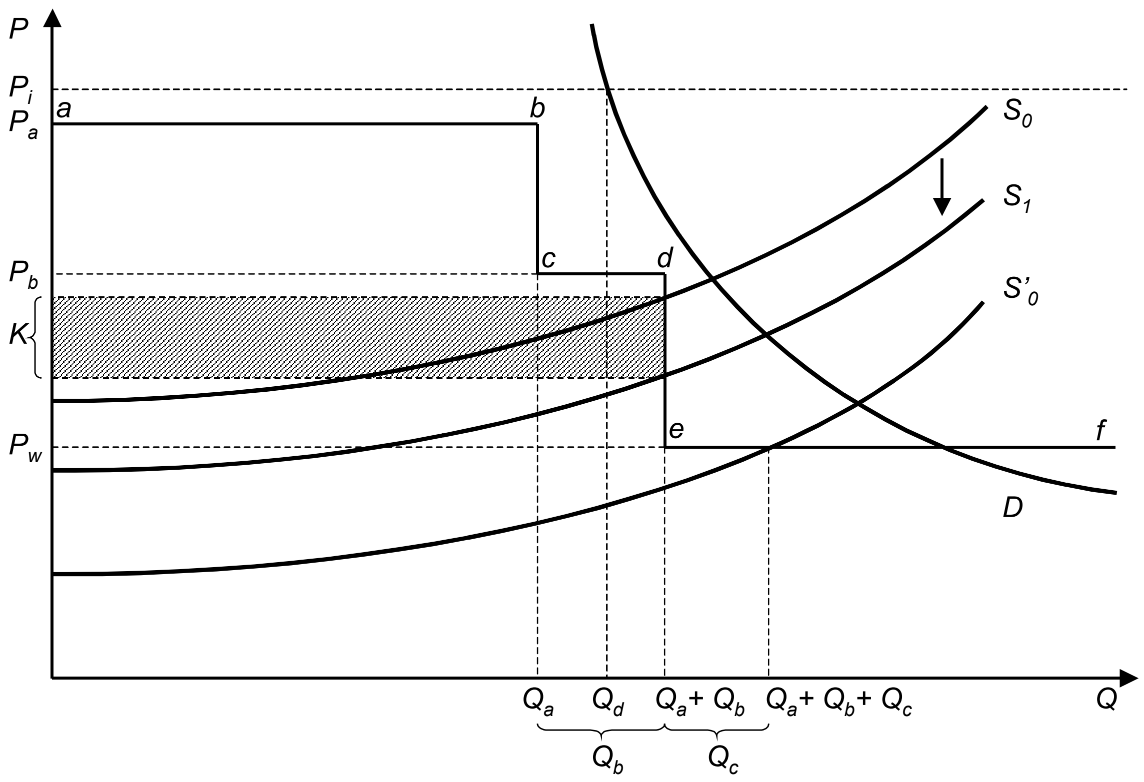
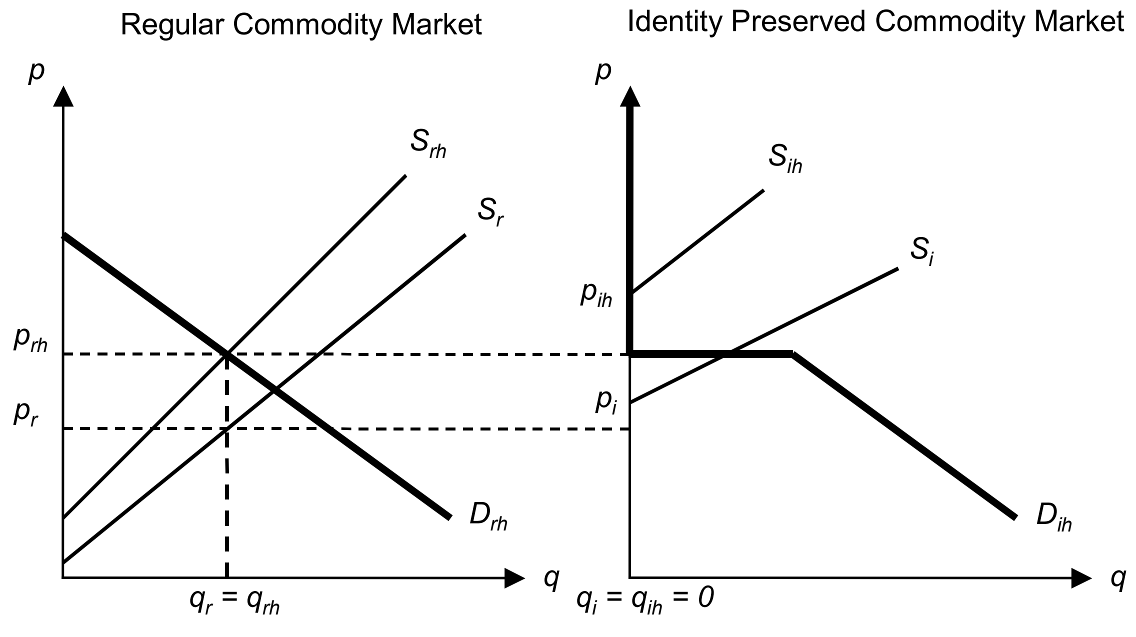
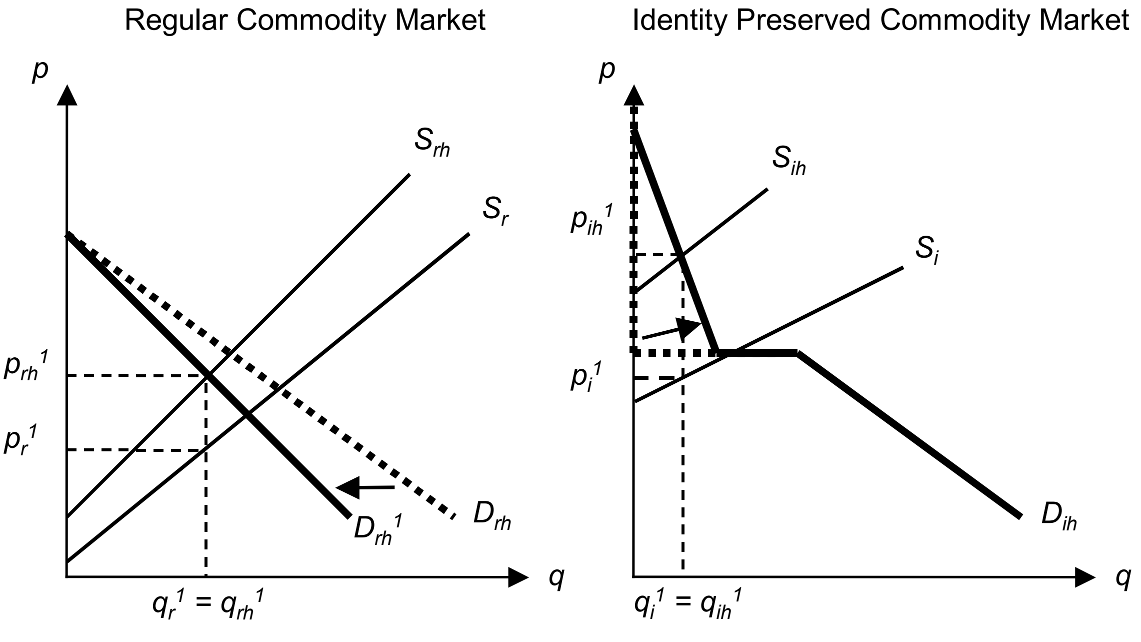


**Figure 3: Quota System of the European Common Sugar Market and Research Benefits of Technological Innovations**



(a) (b)

**Figure 4 : Commodity Markets in the Presence of GMOs and Indifferent Consumers (Desquilbet et al., 2000)**



(a) (b)

**Figure 5 : Commodity Markets in the Presence of GMOs and Differentiated Consumers (Desquilbet et al., 2000)**

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[1] An innovation is drastic if it is priced lower than the existing technology, thus completely taking over the market. An innovation is non-drastic if it is priced competitively with the existing technology.

[2] a Canadian oilseed rape variety

[3] Benbrook (1999) found similar evidence of this yield drag for herbicide tolerant soybeans.

[4] The same conclusions have been drawn by Burton et al. (2000) and Fulton and Keyowski (2000).

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