Farm-level economic impact of Bt maize cultivation in the European Union. Does GM technology reduce or increase the risk?

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Abstract

The paper aims to analyze the farm-level economic impact of insect resistant (Bt) maize cultivation in the European Union (EU). It shows that simple implementation of the technology based on genetically modified (GM) varieties reduces the production risk through stabilization and increase of yield as well as reduction of some variable costs in comparison to conventional technologies. However it also argues that application of GM technology in the EU is influencing the profit risk. The level of profit risk depends largely on costs of coexistence measures enforced by the EU legal regulations of GM production. A cost/benefit calculation was used in order to analyze if cultivation of Bt maize in the EU under coexistence obligations will reduce or increase the profit risk. The analysis is based on data from 7 EU Member States that show economic performance of Bt maize in the period 1998-2006 and data on coexistence costs of GM maize production in Europe.

Introduction

Agricultural production systems are dynamic and change with time. One of the most dynamically developing modern agricultural systems is agriculture based on biotechnology. It is a system of agricultural production that utilizes genetically modified (GM) varieties of agricultural plants and assumes to obtain the highest economic outcome and competitive advantages on the market due to implementation of the biological, technological and organizational progress [Maciejczak 2006]. Ex-ante analysis shows that GM varieties influence the economic performance of agricultural farms [Demont and Tollens 1999, Harmsen et al. 2002, Demont and Tollens 2002]. These findings are largely confirmed by different reports based on ex-post data collected from developed [Secchi et al. 2006, Scatasta et al. 2006, Gomez-Barbero 2007] and developing [Falck-Zapeda and Cohlen 2006, Qaim and Zilbernan 2003] countries. They show that GM varieties could provide economic benefits for the farmers. They increase the yields and reduce some variable costs i.e. pesticide. As a result, farmers are able to obtain higher gross margins from their GM crops comparing to other productions systems (i.e. conventional or organic), despite some additional costs which result from implementation of the innovation i.e. intellectual property rights. However, especially in the EU, there are additional costs associated with the GM cultivation.

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They stem from special coexistence measures which prevent unintended contamination of nonGM products by the GM material.

Introduced on a legal basis as a compulsory measure, the coexistence practices can generate extra costs at all levels of the food supply chain. Generally, the trend followed by the Member States is to place the burden of these costs on the farmers cultivating GM crops.

This paper aims at analyzing the farm-level economic impact of insect resistant (Bt) maize cultivation in the EU. It argues that the GM technology reduces the production risk at the farm level. It also poses a question whether the application of GM technology in the EU influences the profit risk.

Methodology and Data

The nature of agricultural activity is connected with various outcome uncertainties. At the farm, the most uncertain are production outcomes (production risk), mainly due to the nature of agricultural production exposed to weather conditions and dependent on the healthy growth of animals and crops, as well as the price risk, resulting from the volatility of agricultural markets, have a direct and probably the greatest impact on the farm income [Majewski et al. 2007]. The production risk is directly connected with the yield risk, which might be calculated as the probability of yield falling below the insurance product's expected level. Similarly, profit risk – directly connected with the price risk – might be calculated as the probability of revenue falling below the expected level. The probability measure is based on both the mean and variance of yield or revenue – in this case - an indicator of volatility for an individual farm [Makki and Somwaru 1999].

However, with regard to a single farm, another factor influencing a farm profit risk might be also identified. This factor results from additional direct costs associated with production. And the additional direct costs are directly connected with the institutional risk. The institutional risk is the risk associated with changes in the policy framework (agricultural or other policies), which intervene with production and/or marketing decisions and in the end negatively affect the financial result of a farm [EC, 2001]. In this analysis, the compulsory coexistence measures (EU policy) connected with GM production at a farm forms an institutional factor which influences directly the profit risk.

While analyzing the production and profit risks connected to the application of GM technology at agricultural farm, one could take into account its innovative character. Here an innovation in form of GM trait is used to reduce various risks.

Thus in an attempt to assess the influence of biotechnology on the level of risk, yields and profits from Bt maize were compared with other technologies. In this paper, the conventional agricultural production will be used as a reference for the comparison. The comparisons will be based on the Cost/Benefit Analysis (CBA) methodology.

CBA is a set of techniques for evaluating the activity by comparing the economic benefits with the economic costs of the activity. CBA has several objectives. First, it can be used to evaluate the economic merit of a project. Secondly, the results from a series of benefit-cost analyses can be used to compare competing projects. CBA can be used to assess business decisions or to examine the value of public investments. The scope of the methodology shows that the CBA might be used as a narrow financial tool where profits and losses are calculated. However, it might be also used to assess the qualitative values [Treasury Board of Canada Secretariat 1998]. In this paper, the CBA has been used as a simple financial technique, which does not take into account any intangible externalities.

In order to analyze the economic performance of the Bt maize in the EU, an exhaustive literature review has been executed. The aim of the research was to identify the ex-post data for Bt maize cultivation in seven Member States adopters. However, the amount of available data was very limited. Among several theoretical studies, only three papers were identified that show real ex-post data from different seasons in the period 1998-2006. The most exhaustive review has been presented by G. Brookes [2007], who showed data for all seven countries collected from farms as well as data obtained from GM technology providers. Another two reports show data for Spain [Gomez-Barbero and Rodrigues-Cerezo, 2007] and for Spain and Germany [Petzold et al. 2007]. These two reports are based on direct farm interviews.

Importance of biotechnology based agriculture

Although the first commercial GM crops were planted two years earlier, 1996 was the first year in which a significant area (1.66 million hectares) of crops containing GM traits was planted globally. Since then, there has been a significant increase in plantings. Based on the most comprehensive and up to date report edited by C. James [2007], in 2006 the global planted area of GM crops reached 102 million hectares. It is notable that the year-to-year increase of 12 million hectares in 2006 is the second highest in the last 5 years in absolute area, despite the fact that the adoption rates in the United States (US), the principal grower of GM crops for soybean and cotton are already over 80%. In 2006, the GM soybean cultivations accounted for 60.0 million hectares worldwide following maize 27.0 million hectares, cotton and canola, accordingly 17.0 and 8.0 million hectares.

While 22 countries commercialized GM crops in 2006, an additional 29 countries, totaling 51, have granted regulatory approvals for GM crops for import for food and feed use and for release into the environment since 1996. A total of 539 approvals have been granted for 107 events for 21 crops. Of the 51 countries that have granted approvals for GM crops, the US top the list followed by Japan, Canada, South Korea, Australia, the Philippines, Mexico, New Zealand, the European Union and China. Maize has the most events approved (35) followed by cotton (19), canola (14), and soybean (7).

GM in the EU – the issue of coexistence

The European Commission is liberalizing the introduction of GM cultivations in the EU very carefully. The EU decision to introduce labeling thresholds for adventitious presence of genetically modified (GM) material in non-GM products, necessary to safeguard consumer choice, paved the way for a regulated coexistence between GM and non-GM crops. Coexistence in principle refers to the ability of farmers to make a practical choice between conventional, organic or genetically modified crop production, in compliance with the legal obligations for labeling and/or purity criteria [OECD 2000]. Coexistence between GM, conventional and organic farming is governed in the EU by the principle of "subsidiarity"[1]. It means that the Member States are to adopt their own national strategies to promote coexistence. The European Commission (EC) is in charge of gathering and coordinating information on the topic, developing guidelines based on that information and monitoring Member States' progress. Consequently, in 2003 the EC adopted a Recommendation on guidelines for the development of national strategies and best practices to help the Member States develop national legislative or other strategies for coexistence between GM, conventional and organic farming [EC, 2003]. According to these guidelines, coexistence is concerned with the potential economic impact of the admixture of GM and non-GM crops, the identification of workable management measures to minimize admixture and the cost of these measures. Thus coexistence measures and liability laws can generate extra costs at the farm level. Generally, the trend followed by the Member States has been to place the burden of these costs on the farmers cultivating GM crops [EC, 2006]. According to the EC guidelines, the farmer who introduces the new type of production should bear responsibility for implementing the farm management measures necessary to limit gene flow. These extra costs may offset the potential benefits of cultivating GM crops with the result that farmers may no longer find it attractive to cultivate them. Minimizing adventitious GM presence in non-GM crops with cost-effective measures seems to be the only solution to meet the first condition set in the Commission Recommendation that no form of agriculture, be it conventional, organic or agriculture using GMO, should be excluded in the EU.

[1] Defined as the principle that the EU does not take action on a particular subject unless it is more effective than action taken at national, regional or local level (http://europa.eu/scadplus/glossary/subsidiarity_en.htm).

Bt maize cultivations in the EU

Since the World War II, the development of maize growing in Europe has been driven by technological and economic changes. The innovation wave started with the commercialization of hybrid maize in the second half of the 20th century. Until the beginning of the 21st century, the fixed costs of maize production increased, which raised the demand for cost-reducing technological innovations such as biotechnology [Demont and Tollens 2004].

However, the most demanded innovation is a weapon against certain Lepidopteran pests. European corn borer (*Ostrinia nubilalis*, or ECB) is the most damaging one. European corn borer is a very destructive maize insect in Europe and North America and can cause severe economic losses to producers by reducing grain yield and quality. It is estimated that under most effective protection regime ECB on average can reduce yield as much as 5% by the 1st generation and 2.5% by the 2nd generation. Managing ECB can be achieved through resistant hybrids, crop rotation, adjusting planting dates, scouting and the use of insecticides above economic thresholds. Once the borer larvae have moved inside the plant, insecticides and biological measures offer virtually no protection or control. Growing resistant cultivars has been the most efficient and economic approach for controlling this pest [Ma and Subedi 2005].

Table 1. Bt maize plantings in the EU, 1990-2006 (ha)

Year / Country	1998	1999	2000	2001	2002	2003	2003	2005	2006
Spain	22.467	25.071	26.061	11.598	21.004	32.244	58.219	53.225	53.667
Germany	100-200	100-200	100-200	100-200	100-200	100-200	100-200	250	950
France	1.800-3.000	0	0	0	0	0	0	500	520
Portugal	0	1.300	0	0	0	0	0	780	1.250
Czech Rep.	0	0	0	0	0	0	0	270	1.290
Poland	0	0	0	0	0	0	0	0	30
Slovakia	0	0	0	0	0	0	0	0	30
Total	24.367-25.667	25.171-25.271	26.161-26.261	11.698-11.798	21.104-21.204	32.344-32.444	58.419-58.519	55.025	64.650

Source: Brookes, 2007

Bt maize cultivation area in the EU is small (Table 1). In total, the area planted with Bt maize in the EU was 64,500 ha in 2006, equivalent to approximately 0.6% of total EU25 maize plantings, including forage maize area. Currently, only two crop/trait combinations are authorized for planting across the EU: maize tolerant to the herbicide glufosinate ammonium (transformation event T25) and 'Bt' maize expressing a gene from a common soil bacterium (*Bacillus thuringiensis*) that confers resistance to certain Lepidopteran pests (transformation events MON 810 and Bt 176). Only Bt 176 and MON 810 - resistant to the Lepidopteran pests European corn borer and Mediterranean stem borer (*Sesamia nonagroides*) - have been planted in Europe to date. Currently, only varieties of the event MON 810 are available for cultivation: 41 varieties in Spain (from which 25 are included in the EU Common Variety Catalogue), 6 in France, 5 in Germany and 36 have been registered on the EU Common Variety Catalogue [Brookes, 2007].

Bt maize was planted for the first time in 1998 in Spain. Under a voluntary agreement between companies and the government, only small areas, approximately 20 – 25,000 ha or 5% of the total Spanish maize area, were grown from 1998 to 2002. This increased after the end of the agreement in 2003, reaching an estimated area of 58,000 ha in 2006. Small amounts of Bt maize were also planted in France in 1998, in Portugal in 1999 and have been planted in Germany every year since 2000. Renewed activity was seen in 2005, as, in addition to Spain and Germany, France, Portugal and the Czech Republic also report Bt maize cultivations, albeit on limited surfaces.

In 2006, Slovakia became the sixth EU Member State which commercialized Bt maize for the first time. The situation which is taking place in Poland is quite strange. According to the official registers of the Ministry of Environment – a competent authority for GMO in Poland – there are no GM plants cultivated in Poland [Register of GMO]. This is due to the effective legal act on GMO of 2001, which prohibits any GMO cultivations. In 2007, an amendment to this law, which allowed farming of GM varieties under specific conditions, was prepared,. However, this amendment haven't come in force yet. Nonetheless, different sources, both national [i.e. Pietkiewicz, 2007 Gumińska, 2007] and international [i.e. Brookes 2007, or EuropaBio Asociation 2007] mention Poland as a seventh EU Member State where Bt maize is commercially grown, with the area of 30-300 ha (depending on source) in 2006. This situation is now being examined by the state authorities. It is important to mention though that in 2006 the Administrative Court in Warsaw issued a verdict stating that prohibition of GM cultivation is illegal [Niklewicz 2007].

Economic performance of Bt maize in the EU

The ex-post data on economic performance of Bt maize in the EU shows an estimation of the economic advantage of GM crop compared to its conventional counterpart in the EU. This data is presented in the Table 2.

Table 2. Agronomic and economic benefits of adoption of Bt maize in the EU, 1998-2006

Country/ Results	Spain	France	Germany	Czech Rep.	Portugal	Poland	Slovakia
Average yield of Bt. vs. conv. (%)	+1 to +15	+5 to +24	+14 to +15	+9 to +10	+12	Data not available	Data not available
Average Bt. Maize seed premium (euro/ha, 2006)	35	40 to 45	39 to 42	31 to 38	35	45	35
Average reduction of pesticides Bt. vs. conv. (euro/ha)	-35	-50	0	-18	0	0	0
Average impact on gross margin (euro/ha)	+141 (+12%)	+98 to +120 (+16 to +21%)	+83 to +93 (+12 to +14%)	+65 (+15%)	+112 (+22%)	Data not available	Data not available

Source: own calculations based on Brookes, 2007

In five EU Member States where Bt maize is grown, the cultivations resulted in higher yields in comparison to the conventional counterparts. The average increase in the region varied from 8% to 15%, with the highest rate of 24% in France. Due to this increase, farmers obtained certain economic benefits. Those benefits were strengthened by the reduction in the pesticide use. This reduction has been noted in case of Spain, France and Czech Rep., on average of 35 euro/hectare. In other countries, the pesticide use in Bt and conventional maize was similar. However, the abovementioned additional benefits of Bt maize cultivation are connected with additional direct production cost. This cost is a premium for intellectual property rights that a farmer pays for the GM seed. In the analyzed countries, the average premium amounted to 38 euro/hectare in 2006. The production direct costs/benefits analysis executed for the Bt maize shows that the GM technology increases gross margin per hectare. The average increase amounted to 15-17%, with the highest value in Portugal, i.e. 22%.

However, one should remember that the data presented above did not take into account the coexistence measures which need to be applied on mandatory basis when growing GM varieties. The agronomic measures to ensure coexistence at the farm level have been reviewed by Messean et al. [2006], The most robust strategy to ensure coexistence in maize production is the introduction of isolation distances between GM and non-GM fields (so called discard widths). Sowing a non-GM maize buffer strip around GM fields is also effective. Lastly, using GM varieties with different flowering dates compared with non-GM varieties is highly effective but is too dependent on meteorological conditions and hampered by associated yield losses.

Gomez-Barbero and Rodriguez-Cerezo [2007], on the basis of the interviews with farmers in Spain, found out that Bt maize growers obtained on average 81.00 Euro per hectare more than conventional maize growers. They also found out that the maximum coexistence cost that Bt maize growers will be willing to incur before switching to conventional maize or to an alternative crop, would be around that figure.

On other hand Petzoldt et al. [2007], who research German and Spanish farmers did analyze influence of the most effective coexistence measure in maize cultivation, being discards widths. They found out that the real coexistence costs are relatively independent from the GM maize adoption rate in the region, however, they depend on the level of the coexistence measure applied. When the discard width is 20 m. the coexistence cost amounts to 5 euro/hectare, and if it is extended 5 times to 100 m., the cost will grow up 6 times accordingly, i.e. to 30 euro/hectare. In this case, the additional costs occur due to the need of separating harvest, transport, etc.

Implications for farm risk management

If the farmer is facing the uncertainty of outcomes – here defined as yields - in maize production, he will look for solutions which will reduce this risk. In case of the ECB, when the probability of yield reduction is high, the most effective solution becomes to saw GM varieties. Thus with regard to the production risk, when the weather conditions influence the probability of obtaining expected outcome, the agriculture based on biotechnology could provide solutions that might stabilize this outcome reducing other factors which influence the uncertainty. This should be the biggest not pecuniary benefit of the GM varieties utilization in case of maize production. However, the field evidence confirmed that there are another benefits Bt maize could provide to production risk management. In all the EU Member States, the Bt varieties showed higher yields comparing to their conventional counterparts. If the farmer sums up the yield advantage of Bt maize with the savings of yield due to ECB elimination, the benefit he will obtain will exceed the costs connected with implementing the innovation. Besides the stabilization of yield, the farmer might also reduce some variable costs i.e. pesticides.

However, the economic balance of Bt maize reported in the recent publications did not take into account the novel costs that GM farmers will incur in order to ensure coexistence at the farm level, although the coexistence measures are compulsory due to the EU law. None of the reports confirmed also the price difference between GM and nonGM maize that the market paid. The situation that yet there is no market price difference between the products coming from conventional and biotech based agriculture systems is important from the farmer’s point of view. However, while analyzing the choice of systems, the farmer will take into account other benefits than the market ones. Should the farmer choose the Bt maize, he will have to remember that this system of production incurs institutional risk connected with the coexistence measures. This risk will generate additional coexistence costs and, in the final calculation, will influence the profit risk.

The field data showed that the most effective coexistence measure in Bt maize cultivation in Europe, which are discard widths, could generate different costs depends on the isolation distance applied. However, the EU regulators did not fix this distance. It is up to the Member States to define it. A farmer who will perform the cost/benefit analysis before Bt maize sawing will have to take into account the national requirements. Nonetheless, in the analyzed countries this cost does not exceed the benefits the farmers will achieve thanks to the gross margin increase. Using the approach of Gomez-Barbero and Rodriguez-Cerezo [2007], one could state that farmers are willing to cover the costs of coexistence by using all gross margin advantages. Thus the coexistence measures will not increase the profit risk. They might even reduce it through economic advantage of gross margin Bt maize generates.

Conclusions

One of the most dynamically developing modern agricultural systems is agriculture based on biotechnology. In 2006, the global planted area of GM crops reached 102 million hectares. The GM varieties could provide economic benefits for the farmers. As a result, the farmers are able to obtain higher gross margins from their GM crops comparing to other productions systems (i.e. conventional), despite some additional costs which result from innovation implementation i.e. intellectual property rights or special coexistence measures to prevent unintended contamination of nonGM products by the GM material.

Agriculture based on biotechnology is gaining importance also in the European Union, in spite of the careful approach of the European Commission.

The conducted analysis showed that simple implementation Bt maize varieties reduces the production risk through stabilization and increase of yield, as well as reduction of some variable costs in comparison to the conventional technologies. Moreover, the application of GM technology in the EU influences also the profit risk. In this case, the analysis showed that the level of profit risk depends largely on the costs of coexistence measures enforced by the EU legal regulations of GM production. However, in case of Bt maize cultivated in 7 EU Member States, the additional costs did not exceed benefits. Thus, in case of maize, the GM technology did not increase the profit risk. It might stabilize or reduce it.

As the EU is attempting to liberalize its policy with regard to GM cultivation, the farmers might take into account the option to use this technology. This might help them in management of the risk at farm. The more liberal approach of the GM policy, the more this technology would be used, and, as a result, the production risk might be reduced. The agriculture based on biotechnology influences also the profit risk. It might reduce it if there is no price difference between GM and nonGM product. However, the market response to GM products seems to be the most influencing factor of farm profit uncertainty.

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