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The Role of Coordination and Cooperation in Early Adoption of GM Crops: The Case of Bt Maize in Brandenburg, Germany

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Since 2006, several varieties of transgenic Bt maize have been approved for commercial cultivation in Germany. The German regulatory framework for growing these crops comprises moderate ex-ante regulations as well as strict ex-post liability rules to protect conventional and organic farming from possible economic damages caused by transgenic plants and to ensure coexistence. These regulations, however, impose additional costs on those farmers who intend to plant Bt maize. This article addresses the question of how Bt maize-growing farmers perceive the additional costs of regulation and whether coordination or cooperation takes place in order to diminish these costs. In 2006, the authors carried out a case study in the Oderbruch region (Brandenburg, Germany) comprised of eight Bt maize farms and six adjacent non-Bt maize farms. The case study revealed that the costs arising from ex-ante regulations and ex-post liability were only of minor importance to the Bt maize-growing farmers. The predominantly large farms chose *intra*-farm coordination to manage the construction of buffer zones within their own fields and to avoid the planting of Bt maize close to their neighbors. *Inter*-farm coordination or cooperation with adjacent farmers was not regarded as necessary to achieve coexistence.

Key words: Brandenburg, Bt maize, cooperation, coordination, coexistence, ex-ante regulation, ex-post liability, Germany.

Introduction

The introduction of genetically modified (GM) crops for commercial cultivation has raised the question of the coexistence of agricultural production systems. Within the European institutional framework, cross-pollination may cause economic damage to conventional and organic farmers if the produce is subjected to obligatory labelling and, thus, selling is restricted or yields a lower market price compared to the respective conventional or organic products (e.g., Beckmann & Wesseler, 2007). The labelling threshold for adventitious and unavoidable presence of GM traces has been set at 0.9% for food and feed throughout the EU (Commission of the European Communities [CEC], 2003b).

In July 2003, the European Commission published guidelines for designing coexistence regulations for transgenic and non-transgenic plants (CEC, 2003a), according to which no form of agriculture should be excluded from the EU and farmers should be free to choose between farming conventionally or organically as well as using GM crops. However, the guidelines also state clearly that farmers "who introduce the new production type should bear the responsibility of implementing farm management practices necessary to limit gene flow" (CEC, 2003a, pp. 41). The costs of coexistence, thus, are to be borne by the GM farmer. Nevertheless, the guidelines also remark that "groups of farmers in a neighborhood may achieve a significant reduction in the costs related to the segregation of GM and non-GM production types if they coordinate their production on the basis of voluntary agreements" (CEC, 2003a, pp. 46). Against this background, the article investigates theoretically and empirically the costs imposed on the GM farmer by the coexistence regulations and the incentives to reduce these costs by coordination and cooperation.

As the European Commission's mode of decision-making on coexistence regulations follows the principle of subsidiarity, Member States can design and implement national regulations to guarantee coexistence. Within the scope of guidelines formulated by the European Commission, a great diversity of ex-ante regulations and ex-post liability rules has emerged in European countries (Beckmann, Soregaroli, & Wesseler, 2006a). In December 2004, for example, Germany incorporated coexistence rules into the German Genetic Engineering Act (GenTG), including a general code of Good Agricultural Practice (GAP), the creation of a public GMO location register and the definition of ex-post liability rules. In line with the EU regulations, GM farmers in Germany have to bear the (additional) costs of ex-ante regulations and ex-post liability that emerge from the GenTG, including field registration in a national cadastre, compliance with security measures, and liability in case of damages incurred (GenTG, 2006).

In this article, we first aim at identifying and assessing the additional costs for the GM farmer arising from ex-ante regulations and ex-post liability rules defined by the legal framework in Germany. Secondly, we address the question of whether these costs could be reduced through farmers' coordination and cooperation. The empirical analysis is based on case study interviews with eight *Bacillus thuringiensis* (Bt) maize-growing farmers and six of their adjacent neighbors in the federal state of Brandenburg, where coexistence between GM and non-GM farms can already be observed.

In the next section, we give a short introduction to the legal background of GM cultivation in Germany and the development of Bt maize cultivation. The following section provides economic data on the benefits and costs of Bt maize adoption and the potential costs of ex-ante regulation and ex-post liability. Here, we also describe the role of cooperation and coordination for cost reduction. We then present a brief overview of the case study carried out in the Oderbruch region on Brandenburg in 2006. Finally, we discuss the results from the empirical analysis, finishing the article with some conclusions.

Coexistence Regulations and Bt Maize Cultivation in Germany

Germany has been among the first Member States of the European Union introducing coexistence regulations into their national legislation (Beckmann et al., 2006a). Since 2006, Germany has also been one of the five European States in which Bt maize is increasingly being grown (together with the Czech Republic, France, Portugal, Slovakia, and Spain). In the following section, the legal background of coexistence and the development of Bt maize cultivation are briefly introduced.

Legal Background of Bt Maize Cultivation in Germany

Regulations concerning the cultivation of GM crops are embedded in the German Genetic Engineering Act (GenTG), dating back to 1990. In 2004, the act underwent a partial amendment under the former red-green coalition (Social Democratic Party [SPD] and Green Party) to include coexistence regulations, such as the establishment of a public GMO location register (§16a, GenTG) and compliance with GAP (§16b, GenTG) as forms of ex-ante regulation, and the definition of ex-post liability rules (§36a, GenTG). Coming into force in 2005, these basic regulations are still in place, although the definition of GAP was modified significantly in 2008.

The GMO location register is operated by the Federal Office of Consumer Protection and Food Safety (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit [BVL]), which is the supreme authority responsible for the field of genetic engineering in Germany. The register provides detailed information on the planting of GM crops in order to monitor unanticipated environmental and health effects (Vaasen, Gathmann, & Bartsch, 2006) and is divided into a public part—which is freely accessible over the Internet—and a non-public part. The public part contains information on field locations and types of GM crops planted. The non-public part comprises the personal data of GM farmers. For reasons of data privacy, information from this part is only given upon request to persons with legitimate interests, such as neighboring farmers. Cultivation of GM crops must be registered at least 90 days in advance of planting (§16a, GenTG), and any subsequent change in the cultivation of GM crops must be announced immediately on the public location register.

Farmers planting GM crops must, in addition, comply with the general code of GAP (§16b, GenTG). Within their duty of taking precautions, GM farmers must undertake measures to prevent cross-pollination of neighboring fields and wildflowers as well as the contamination of neighboring land. However, the GenTG lacks any concrete specification of measures that are sufficient to keep cross-pollination below the EU-wide labelling threshold of 0.9% for adventitious and technically inevitable GM traces in food and feed. From 2005 to 2007, the specific rules of the GAP were not defined by law, partly because concrete and scientifically based safety measures to keep gene outcrossing below the labelling threshold of 0.9% were not yet agreed upon. German GM farmers had to rely on recommendations from GM seed companies, which recommended buffer zones of 20 m to keep cross-pollination below the labelling threshold (Weber, Bringezu, Pohl, & Gerstenkorn, 2006). In 2008, a specific regulation on GM crop production (GenTPflEV, 2008) dealing with GAP came into force in Germany. According to this regulation, the GM farmer is now obliged to inform his neighbor(s) about intended GM cultivation at least three month prior to planting (§3, GenTPflEV). Furthermore, the GM farmer is responsible for careful handling and harvest-

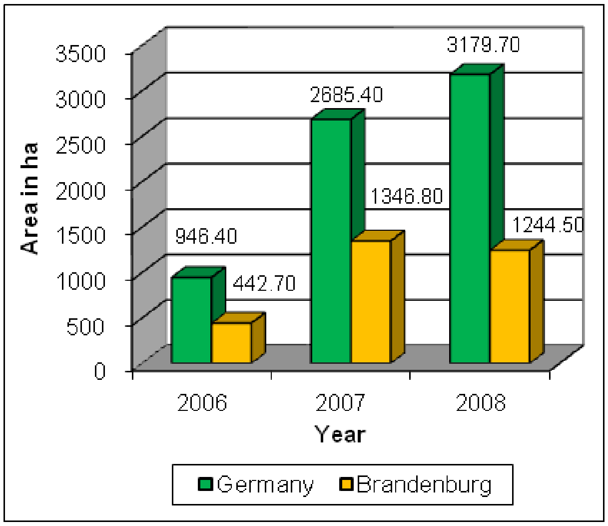

Figure 1. Bt maize cultivation in Germany compared to Bt maize cultivation in Brandenburg.

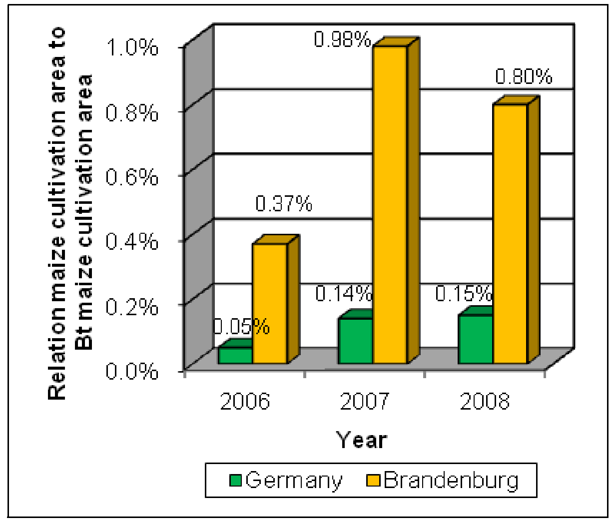

Figure 2. Relation of Bt maize cultivation area to total maize cultivation area in Germany and Brandenburg.

ing of GM crops and correct on-farm labelling (§§6, 7, 8, GenTPflEV). S/he has to remove secondary growth on his fields (§10, GenTPflEV) and to keep records on GM cultivation over a period of five years (§12, GenTPflEV). Beyond this, the regulation defines Bt maize-specific distance requirements of 150 m to adjacent conventional maize stands and 300 m to organic maize fields. These distances, however, can be reduced by private agreements among neighboring farms.

In cases of ex-post liability, Bt maize-growing farmers in a region are jointly and severally liable for damages caused by, for example, gene outcrossing to neighboring maize plants (§32, GenTG). Furthermore, GM farmers are strictly liable; that is, even if they have met all requirements of the GAP, they are not exempt from third-party liability claims. Although the GAP was only defined legally in 2008, the previous strict liability rules persist.

In summary, and compared with other EU countries, the German coexistence regulations can be characterized as comprising strict ex-post liability rules with moderate ex-ante regulation. However, the ex-ante regulations were tightened significantly in 2008.

The Cultivation of Bt Maize in Germany

Up to now, Bt maize has been the only transgenic crop plant approved for commercial cultivation in the EU. Bt maize expresses the activated protein Cry1A(b) from the soil bacterium *Bacillus thuringiensis* BERLINER, which targets the larvae of the European Corn Borer (ECB, *Ostrinia nubilalis* HÜBNER) when feeding on the plant. The annual ECB-infested area in Germany is estimated to be 356,000 ha or 21% of the total maize area grown (Degenhardt, Horstmann, & Mülleder, 2003). Since the end of 2005, five transgenic varieties of Bt maize MON810 have been approved for commercial cultivation in Germany and, in 2006, were planted on 950 ha throughout the country, including 443 ha in the federal state of Brandenburg (BVL, 2007a). The main concentration of Bt maize cultivation in Brandenburg lies in the Oderbruch region in the rural district of Märkisch-Oderland—close to the Polish border—where infestation rates of ECB are reported to be high (Schröder, Goetzke, & Kuntzke, 2006). In 2007, commercial cultivation was increased up to 2,690 ha at the national level, 1,344 ha of which was cultivated in Brandenburg. In 2008, a slight decrease took place, with 1,244 ha cultivated in Brandenburg, though still exhibiting an increase of 3,179.7 ha nationally (BVL, 2007a) (Figure 1).

On the national level, only 0.05% of the maize area was cultivated with Bt maize in 2006. This increased up to 0.14% in 2007 and then stagnated with 0.15% in 2008. The case of Brandenburg, however, displays a different picture. Here, Bt maize accounted for 0.37% of the total area under maize production in 2006 and increased up to 0.98% in 2007, but decreased to 0.80% in 2008 (Figure 2). Compared to early adoption rates in the United States or in Spain, these shares are still very small.

Costs of Ex-ante Regulation and Ex-post Liability, Adoption of Bt Maize, and the Role of Cooperation

The decision at the farm level to adopt GM crops and to cooperate with neighbors has been analyzed theoretically elsewhere (Beckmann et al., 2006a, 2006b; Beckmann & Schleyer, 2007; Beckmann & Wesseler, 2007). These authors have used a rational-choice framework, where farmers evaluate the benefits and costs of Bt maize adoption as well as of cooperation with other farmers under uncertainty and irreversibility. The authors of these articles have hypothesized that farmers will adopt Bt maize if the expected incremental benefits exceed the expected costs of ex-ante regulation and ex-post liability plus the net-costs of irreversibility. The decision to cooperate, however, is very much affected by the number and types (conventional or organic) of neighboring farms, the possible benefits that could be achieved through cooperation, and the costs of coordination and cooperation itself. In Germany, the incremental benefits of growing Bt maize in regions that are highly affected by the ECB have been estimated at up to €93/ha (Degenhardt et al., 2003). Brookes (2007) reviews gross margin gains for several European countries according to different sources. In Spain, for instance, gross margin benefits from €67/ha to €330/ha have been observed, whereas for France, average gains from Bt maize cultivation ranged from €98/ha in 2005 to €120/ha in 2006. At present, cost estimates for ex-ante regulation and ex-post liability do not, however, exist for Germany. The same holds for the cost of cooperation between neighbors. In the following, the costs arising from ex-ante regulations and ex-post liability will be categorized and the options for cooperation described.

Costs Arising from Ex-ante Regulations and Ex-post Liability

The legal framework of ex-ante regulations and ex-post liability in Germany can cause additional costs to the farmer who decides to grow GM crops. These costs can be classified as

1. administration and publication costs,
2. damage prevention and coexistence-measure costs, and
3. damage and liability costs.

Administration and Publication Costs. The cultivation of Bt maize must be announced in the GMO location register of the BVL, which can cause both direct and indirect costs:

- The act of registration itself is closely connected with additional work and expense for the GM farmer.
- Certain data from the GMO location register is easily accessible for free via the Internet, such as the exact location of the GM field. In the past, this has facilitated field-destruction activity by fierce opponents of GM technology.

Damage Prevention and Coexistence-Measure Costs. In order to avoid possible damage, for example, through cross-pollination, the farmer is obliged to meet GAP standards. Apart from direct costs due to distance requirements, indirect information costs also have to be taken into account:

- Since the GenTG does not provide recommendations on reasonable distance requirements, the GM farmer has to gather information by himself about adequate coexistence measures to avoid damage.
- Safety measures have to be implemented on the farm level. Theoretically, the farmer can choose from a set of measures, which are able to ensure the labelling threshold of 0.9% on neighboring fields.

Messean, Angevin, Gómez-Barbero, Menrad, and Rodríguez-Cerezo (2006) provide a set of on-farm measures to reduce the above mentioned risks and to guarantee coexistence:

a) Isolation distances between GM and non-GM fields of the same species (different crop)
b) Use of GM and non-GM crops with different flowering times (time isolation)
c) Installation of non-GM buffer zones of the same crop around GM fields

Messean et al. (2006) also review some additional on-farm costs arising from individual coexistence measures. For instance, the sowing of different maize varieties for time isolation results in notable additional costs, ranging from €46 to €201/ha, which can be explained by significant variety-based yield reduction. Additional on-farm costs for creating buffer zones vary from €60.54 to €78.07/ha, depending on the size of the GM field, the width of the buffer zone, and the adoption rate of GM crops in the region. The authors further note that the smaller the GM fields (<1 ha), the higher the on-farm costs per ha caused by the establishment of buffer zones.

Damage and Liability Costs. Even if a farmer meets the requirements of the GAP code, s/he is still jointly and severally, as well as strictly, liable for possible damages. Estimation of damage and liability costs depends on (a) the expected damage, (b) the probability of damage occurrence, and (c) the probability that the farmer will actually be held liable for the damage:

- The magnitude of damage and liability costs is influenced by (1) the price difference between GM, conventional, and organic products, (2) the quantity of products affected, and (3) the labelling threshold.
- The probability of damage occurrence is strongly influenced by the security measures taken and the type of GM crop(s) grown.
- The probability that the farmer will be held liable depends on relationships with neighbors and the possibility/likelihood of an amicable agreement.

Apart from these direct costs, possible costs arising from lawsuits also have to be taken into consideration (Beckmann & Wesseler, 2007).

It has to be kept in mind that Bt maize will only be adopted if the benefits outweigh the costs (Beckmann & Wesseler, 2007). According to Degenhardt et al. (2003), Bt maize cultivation in the Oderbruch region can yield benefits of up to €93/ha when compared to other measures, such as the application of insecticides or antagonists. However, these benefits have to be compared to the costs of Bt maize cultivation, which can vary according to the set of ex-ante regulations and ex-post liability rules in place (Demont & Devos, 2008; Demont et al., 2007). Especially rigid ex-ante regulation (e.g., huge distance requirements) combined with strict ex-post liability is likely to reduce the net-benefit of Bt maize cultivation significantly. Furthermore, strict ex-post liability rules can entail significant costs for small farms (Soregaroli & Wesseler, 2005). Economic losses due to coexistence measures can be minimized by clustering GM fields and through establishment of non-GM buffer zones only around whole clusters. Yet, the economic analysis of Messean et al. (2006) does not take into account additional administrative costs or costs of cooperation necessary to achieve such measures.

Forms of Coordination and Cooperation

According to the German legal framework, GM farmers bear the burden of ensuring coexistence exclusively. However, we argue that both GM farmers and their non-GM neighbors could contribute to coexistence through coordination or cooperation. Coordination can take place within a single farm (intra-farm coordination) or between two adjacent farmers (inter-farm coordination). For intra-farm coordination, GM farmers can arrange their own fields to keep maximum distances from neighbors, adjust field sizes to reduce both the risk of cross-pollination and costs of additional buffer zones or install isolation distances. Inter-farm coordination involves GM farmers as well as their non-GM neighbors, with GM farmers informing neighbors about the exact location of their GM fields—information that can also be obtained from the public location register. Both kinds of farmers can agree on planting different varieties or adjusting their cultivation plans in order to prevent short distances between GM and non-GM maize fields.

Cooperation itself can be defined as a special form of inter-farm coordination. Beckmann and Schleyer (2007) observe three new forms of agricultural cooperation resulting from the approval of transgenic varieties for commercial cultivation in the EU: (1) the development of so-called GMO-free zones, (2) the creation of potential GMO zones, or (3) cooperation for coexistence.

Data on the development of GMO-free zones in Germany indicate that the most common form of explicit cooperation to cope with agro-biotechnology is avoidance, with adjoining farms signing contracts to refrain from growing or feeding GM crops.

We assume that in the special case of Bt maize it is very easy to join a GMO-free zone if (a) little or no maize at all is grown in the region, (b) the ECB is of minor importance or can be controlled easily by other means than Bt, or (c) the region is characterized by a high density of organic farms which are not permitted to make use of GM technology. Although examining a different institutional environment, Furtan, Güzel, and Weseen (2007), for example, have reported positive welfare effects through the formation of an organic club (a GMO-free zone).

Alternatively, neighboring farmers could cooperate to form a GMO zone, where only GM crops are grown. This is generally the case where adjacent farmers rank the value of GM production higher than the value of non-GM production.

In cases of cooperation for coexistence, one farmer attaches a higher benefit to non-GM production, whereas her/his neighbor perceives a higher value from GM production. Especially in areas with small-scale agricultural production, where the creation of buffer zones is assumed to impose higher costs on the GM farmer, adjacent farmers can cooperate for coexistence by changing fields to maintain safe distances.

In a region with GM farms as well as conventional or organic ones, coexistence can create additional costs. We argue that cooperation between neighboring farmers becomes more beneficial when the costs of intra-farm coordination are perceived to be higher and when cooperation can reduce the costs of ex-ante regulation and ex-post liability significantly. One still has to keep in mind that coordination and cooperation themselves are also a new source of additional costs, since agreements have to be made, monitored, and enforced.

Further, cooperation is not only observed among farmers, but also between farmers and upstream enterprises, such as seed companies. In 2005, the seed and grain trading company Märkische Kraftfutter GmbH (Märka) implemented a practical quality assurance system. Together with Monsanto Agrar Deutschland GmbH and Pioneer Hi-Bred International, Inc., the company allowed GM grain maize to be commercialized. At the same time, it guaranteed farmers that their conventional grain maize grown adjacent to Bt maize would be bought, regardless of possible GMO traces and without any price reduction, as long as the labelling threshold was not exceeded (Pohl, Gerstenkorn, Thierfelder, & Degenhardt, 2005; Weber et al., 2006). GM farmers participating in this project voluntarily implemented GAP to keep GMO traces below the labelling threshold. In turn, the trader was responsible for further segregation and labelling. In defining a 20 m separation distance for secure compliance with the 0.9% threshold, the Märka system relied on the outcomes of several studies on pollen movement and cross-pollination. Additionally, GM farmers were asked to inform adjacent neighbors within a 100 m range from Bt maize fields and to harvest, store, and transport GM maize and non-GM maize separately as well as to clean machinery adequately (Pohl et al., 2005).

A Case Study of Bt Maize Cultivation in Brandenburg, Germany

The Case-Study Region

The administrative district of Märkisch-Oderland, in the German federal state of Brandenburg, was selected as a case-study region. The Oderbruch region is located within this district and has exhibited an increasing incidence of the ECB after the pest was first reported in 1986 (Schröder et al., 2006). Especially in grain maize production, the ECB can cause yearly on-farm losses of up to 30% (Piprek, 2005). The insect can, however, be controlled by a variety of measures, including tilling operations, chemical and biological pest control, and—since 2006—the cultivation of Bt maize, though these measures differ significantly in their effectiveness. Although tilling is reported to be a powerful precaution against the ECB, it is not suitable for many parts of the Oderbruch region because of soil characteristics there. Chemical control has an efficiency factor of 70-90%, but is also connected with two major disadvantages. First, in 2006 only one pesticide was approved for the chemical control of the ECB in maize in Germany (BVL, 2007b), depriving the farmer of chemical alternatives for resistance management. Second, control is technically difficult because, at the time of spraying, the maize plants have already reached a height of 1.5 m and special machinery is needed. Furthermore, the farmer is restricted by a narrow time frame for insecticide application, since, as soon as the ECB larvae have entered the maize stem, surface spraying is no longer useful.

Biological control with the natural antagonist *Trichogramma brassicae* is reported to be less effective than chemical control in the Oderbruch region and application is time- and cost-intensive. Government aid is given for *Trichogramma*-control in some parts of Germany, but this does not apply to Brandenburg (Winkler, 2005).

Bt maize MON810, which is the only GM crop approved for commercial production in Germany, contains a δ-endotoxin of the soil bacterium *Bacillus thuringiensis*, which is lethal to the larvae of lepidopteran species, such as the ECB. The efficiency factor of this technology is reported to be close to 100% (Degenhardt et al., 2003). Since its first approval for field trials in 1998, Bt maize MON 810 has been tested on-farm in Brandenburg. Some of the farmers who engaged in these field trials switched to commercial Bt maize cultivation in 2006.

Sample Selection and Farm Characteristics

Eight farmers were identified in the rural district of Märkisch-Oderland who grew Bt maize in 2006. All of them were interviewed using a standardized questionnaire, consisting of questions regarding on-farm Bt maize cultivation, the perception of ex-ante regulation and ex-post liability rules, as well as questions on coordination and cooperation. Some of the Bt maize-growing farmers passed on the names of their adjacent neighbors, whom we were able to interview subsequently. Since maize pollen can spread over short distances, the GM farmers were asked to provide information on those of their adjacent neighbors who were also growing maize. It was of major interest whether adjacent farmers were informed about the Bt maize cultivation or if any coordination or even cooperation took place to avoid cross-pollination. Furthermore, we asked if the farmers were (still) on friendly terms with their neighbors, or if the relationship had changed due to Bt maize cultivation. Since the decision to cultivate GM crops on the farm level not only depends on the cost assigned to this adoption, we also assessed the benefits of Bt maize cultivation in the study area.

It was assumed that the seed and grain trading company Märka contributed to cooperation and, therefore, we also investigated whether both the GM farmers and their neighbors knew about or made use of the purchase guarantee for adjacent maize.

We chose the case-study approach for data collection and analysis because very few farmers were growing Bt maize in the region. The data collected from the GM farmers was verified by the respective statements of the six neighbors.

Quantitative data on Bt maize cultivation was also collected, but statistical evaluation was not possible because of the small sample size. Results obtained from each farm regarding coordination and cooperation as well as neighbor relationships are described in the following paragraph (see also Table 1).

Farmer 1 had five neighbors, two of them organic farms and the rest conventional farms. The organic farms were not growing maize at all. One of the conventional farmers also showed interest in growing Bt maize, but up to now he had refrained from doing so because of the public location register. In the event of an increase in ECB infestation, however, he would reconsider his decision. Adjacent neighbors had been informed in time about the planting of Bt maize and field location. The relationship to large (conventional) farmers was described as "good" and to one of the organic farmers as "difficult," with the latter expressing strong resentment about the adoption of GM crops. Consequently, Farmer 1 tried to avoid unnecessary provocation by not planting Bt maize close to the fields of the organic farm. However, the relationship did not improve. Cooperation for coexistence was not observed. Farmer 1 knew about the Märka system, but none of the adjacent farmers nor he had to make use of it, since sufficient safety distances had been kept.

Farmer 2 adopted Bt maize cultivation in 2006 on an area of 17 ha, 15 ha being the actual Bt maize plot size, with a 2 ha buffer zone around the field. The field was situated close to a neighboring field where no maize was grown. This resulted in inter-farm coordination, since the GM farmer notified his adjacent neighbor about planting Bt maize close to his fields. Intra-farm coordination thus took place by means of keeping to recommended distance requirements, installing a 25 m buffer zone around the Bt maize plot. Farmer 2 reported having informed the adjacent farmer prior to planting Bt maize. Cooperation for coexistence, however, did not take place. Neither of the two neighbors saw any need for coordinating planting areas or times, since they did not expect any damage. No information was exchanged about possible damage and liability issues. The relationship was described as "good" and did not change because of Bt maize cultivation.

Farmer 3 started to grow Bt maize on a very small trial area in 2006. The farm had six neighbors, one of them an organic farm, which did not grow maize at all. Three neighbors were large farms, also growing maize. These farms showed much interest in the trial carried out at Farm 3 and also considered a partial switch to Bt maize in subsequent years. All neighbors had been informed about Bt maize cultivation in advance. Cooperation for coexistence was not reported. The relationship between the GM-farmer and the neighbors was described as "good," but changed for the worse with the organic farm.

Farmer 4 had ten neighbors, most of them growing conventional maize and only one producing organically. Some of the adjacent conventional farmers had also considered Bt maize cultivation. The neighbors had been informed when it was regarded as reasonable. No cooperation for coexistence was observed. The relationships were reported as "good" and did not change over time. Farmer 4 informed his neighbors about the Märka system, but no one made use of it.

Farmer 5 had five neighbors and stated that he had informed all of them on intended Bt maize cultivation, contacting them personally if cultivation was planned directly adjacent to neighboring maize stands. Two neighbors had not been informed directly, because of the great distance of several kilometers between the GM field and their conventional maize stands. Cooperation for coexistence was not regarded as necessary and no information about potential damages was exchanged. The Märka system was well known, but not used. The GM farmer described the relationship to his neighbors as "good," and this description was confirmed by the neighbors.

Farmer 6 had six neighbors in total, four of them farming conventionally and two organically. Three

Table 1. Comparison of Bt maize growing farms and adjacent non-GM farms.

			Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8
Farm-related data	Maize production in 2006	**Farm Size (AUP[a] in ha)**	530	650	2 200	1 350	1 700	1 080	3 000	505
		Maize area in ha	110	130	263	246	400	120	500	250
		% Bt of AUP	5.7	2.3	0.2	3.7	3.4	2.3	1.3	3.0
		% Bt of maize area	27.3	11.5	1.7	20.3	14.5	20.8	8.0	6.0
Information on	Neighboring farms	**Number of adjacent farms**	5	2	6	10	5	6	6	6
		Production type of adjacent farms*	3 C, 2 O	2 C	5 C, 1 O	9 C, 1 O	5 C	4 C, 2 O	4 C, 2 O	6 C
		Acceptance of Bt in adjacent farms	Good, except organic farm	Not known	Good	Good	Good	Good	Good	Good
		Relationship to neighbors	Good, except organic farm	Good to very good	Good	Good	Good except one farm	Good	Very good to very bad	Good
		Change of relationship due to Bt cultivation	No	No	Only to organic farm	No	No	No	No	No
	Coordination and cooperation	**Field allocation****	1	3	1	1 and 3	1 and 3	2 and 5	2 and 4	1
		Buffer zone/ Isolation distance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Information about intended Bt cultivation	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
		Cultivation plans, varieties	No	No	No	No	No	No	No	No
		Cooperation	No	No	No	No	No	No	No	No

[a] AUP: Area under (agricultural) production per farm in ha.

** C=conventional; O=organic*

*** (1) Within own maize fields; (2) Bordering non-maize field (own); (3) Bordering non-maize field (not own); (4) Bordering maize field (own), (5) Bordering maize field (not own)*

neighbors were growing maize. Farmer 6 did not grow Bt maize close to the organic farms, to avoid confrontation. In cases where fields adjoined, the GM farmer claimed that he had informed all of his neighbors orally. One neighbor stated that he had not been informed, but traced this back to the huge distance between the GM field and his own (2 km). One neighbor was situated between the fields of two GM farms (Farm 6 and 7) and had not been informed either. Cooperation did not take place and no information about damage or liability had been exchanged. Farmer 6 knew about the Märka system, but the neighbors did not. The relationship was described as "normal" and did not change.

Farmer 7 had six to seven neighbors, two of them organic farms, with one farm growing conventional maize. This neighbor was interested in also switching to Bt maize, but was afraid of his milk being refused by the dairies and becoming a target for anti-GM activists. Farmer 7 had not informed his neighbors, because they seemed not to care about Bt maize cultivation and, therefore, cooperation was not observed. The relationships ranged from "very good" to "very bad," but not due to GM. The Märka system was known, but not made use of.

Farmer 8 had six neighbors, none of them farming organically. Four adjacent farmers were growing conventional maize. One of the neighbors was also a GM farmer (Farmer 7) but a clustering of GM fields was not taken into consideration. The neighbors had been informed orally. Cooperation was not regarded as being necessary and, thus, did not take place. The relationship to all neighboring farmers was described as “good.” Farmer 8 was acquainted with the Märka system, but did not use it.

Regarding the benefits of Bt maize cultivation, we asked the GM farmers as well as their neighbors to give reasons for adopting (or not adopting) Bt maize. Interestingly, all GM farmers stated to have grown Bt maize because the ECB could not be controlled effectively with other measures, with 87% also attributing their adoption to a higher grain quality with Bt maize when compared to non-Bt maize, because of the former’s reduced mycotoxin content. Protecting the environment by using Bt maize rather than insecticides to combat the corn borer was said to be even more important to the farmers (75%) than increasing their income (62.5%). On the other hand, 50% of the conventional farmers did not switch to Bt maize cultivation because they could apply other measures effectively and were afraid of the strict liability rules in case of damage (50%). Our results on the perception of Bt maize benefits are partly in line with observations made by Gómez-Barbero, Berbel, and Rodríguez-Cerezo (2008) in Spain, where the usefulness of the technology was also perceived to be higher among adopters compared to other conventional farmers.

As can be seen from the interviews with the eight Bt maize-growing farmers in the Oderbruch region, coordination in terms of informing adjacent neighbors was a common practice, though not required under German legislation in 2006. Also, necessary distance requirements or buffer zones of conventional maize were kept around the Bt maize stands. Many Bt maize-growing farmers refrained from growing GM maize close to organic fields, even if these farmers did not grow any maize at all. Specific cooperation for coexistence, however, was not observed in any case.

Cost Estimation and Strategies for Coexistence

After the foregoing brief characterization of the interviewed farmers, we now provide an assessment of ex-ante regulation and ex-post liability costs, as well as the subjective benefits of Bt maize cultivation.

Administration and Publication Costs Due to Public Location Register

In the first place, registration in the public location register is an additional time-consuming activity, and farmers have to decide at least three months in advance where to plant Bt maize and other crops. Once registered, they can only plant Bt maize in the areas initially intended for this purpose and might be forced to change their cultivation plans if an adjacent farmer decides to plant maize close to an already-registered Bt maize field. The interview results reflect these additional costs, since half of the Bt maize-growing farmers regarded the registration process as “cost-intensive.” Registration is also accompanied by the publication of farm-related and personal data, which can be obtained upon request. Seven out of eight farmers reported personal disadvantages because of this publication policy. Five GM farmers became direct targets of anti-GM campaigns, such as field destruction and other hostile actions. There is no doubt that anti-GM groups have a clear interest in obtaining the personal data of GM farmers to exert pressure directly. For instance, the “Bantam” Initiative, (Bantam-Mais, n.d.), which is supported by Greenpeace, the German Society for Nature Conservation (NABU), several church groups, and stakeholders of the organic movement, aims at obtaining legitimate access to the non-public part of the location register—and, thereby, the ability to view the personal data of GM farmers in the region—by planting old varieties of sweet maize close to GM maize stands.

Damage Prevention, Coexistence Measures, and Their Costs

For the planting seasons 2006 and 2007, the GenTG (dated 17th March 2006) did not contain concrete measures for coexistence with respect to GAP, and only seed companies provided recommendations on coexistence management, such as distance requirements or guidance for the cleaning of machinery. Every GM farmer participating in our study kept at least a 20 m buffer zone of non-GM maize around the Bt maize stands, as suggested by Monsanto Agrar Deutschland GmbH. The majority of them were even willing to use distances up to 100 m or more. Interestingly enough, seven out of eight GM farmers linked no extra or only negligible costs to the establishment of buffer zones. Only one farmer described the additional costs as high. The reason can be found in their farm structures. The smallest GM farm comprised an area of 500 ha, and the largest was 3,000 ha. The adjacent farms were even larger, with areas of up to 7,000 ha. In relation to the total area under cultivation, the percentage of Bt maize never exceeded 6%. This indicates that Bt maize cultivation is still confined to rather small areas related to on-farm planting density of maize (ranging from 11% to 49%) and can, thus, be coordinated easily within a farm. We observed the cultivation of Bt maize prevalently in the midst of a farm's conventional maize stands, which then served as buffer zones. Further, since most of the maize was grown for intra-farm cattle feeding, strict segregation of GM and non-GM harvests was not necessary on the farm level. Therefore, we conclude that buffer zones, if explicitly installed, could be maintained at low opportunity costs for the GM farmer.

All farmers were very well informed about the distance requirements and kept buffer zones. Since most of the farmers had already carried out field studies with GM-maize, we assume that obtaining information on safety measures was not linked to high costs.

Evaluation of Liability Rules and Risk of Damage

Existing ex-post liability rules did not have any significant influence on the decision to grow Bt maize. The GM farmers were able to reduce the risk of cross-pollination and, thus, economic damage to their neighbors by spatial allocation of their Bt maize fields. Most of the GM farmers planned to increase Bt maize cultivation in subsequent years, regardless of changes in the liability rules. Yet, three of the six non-GM neighbors stated that they had not grown Bt maize due to remaining uncertainties as to liability in case of damage. According to Beckmann and Wesseler (2007), damage may occur if GM-adjacent conventional maize comes to exceed a pre-defined threshold level for adventitious or technically unavoidable GM traces and, consequently, yields a lower market price due to GM labelling. Conversely, damage would not occur if the threshold was not exceeded or if GM products were marketed at the same price as non-GM products. The farms we analyzed were mainly growing maize for silage, which was not intended for sale. No damage is expected if silo maize with an adventitious presence of GM beyond 0.9% is fed to livestock, since neither meat, milk, nor eggs must be labelled according to EU legislation, even if GM products were used during the production process. Thus, damage can only occur in cases of market sale, where the product has to be labelled and yields a lower price as a result. In Brandenburg, GM grain maize could be sold without any problem in 2006. The same holds true for conventional grain maize exceeding the labelling threshold. Against all expectations, both conventional grain maize and GM grain maize of comparable quality yielded €120/ton when sold to Märka in 2006. We conclude that, even in the case of GM traces beyond the threshold, no economic damage occurred. However, this only applies to the farms we considered within our case study and should not be generalized. It can only be claimed that in 2006 none of the GM farmers faced any damage or liability costs. This could be due to two reasons. First, all farmers kept distance requirements, which were reported to be sufficient to keep cross-pollination below the threshold level. Second, even in cases of market sale, the threshold would have played a negligible role since, at least for grain maize, the Märka system ensured against economic damages.

However, it should be noted that, even if there is no price difference between Bt and conventional maize, possible damages for organic farms may occur. At least in the region under study, no such cases were reported, partly because many neighboring organic farms did not grow maize and the GM farmers voluntarily kept greater-than-recommended isolation distances.

Coordination and Cooperation Between Neighbors

As we have already pointed out, neighboring farmers have incentives to coordinate if this reduces the costs of coexistence. Different forms of coordination for coexistence are possible, ranging from relatively easy intra-farm coordination, where no external actors are involved, to inter-farm coordination and cooperation, where GM farmers closely interact with their neighbors or downstream enterprises, such as Märka.

According to our definition, intra-farm coordination consists of three general components: (1) field allocation, (2) field size, and (3) isolation distances. Regarding the first two measures, the GM farmer can decide freely on whether to adopt them or not, whereas the last option is already prescribed by law, even though legally defined safety distances are still lacking. In our case study, we observed that all farmers willingly kept distance requirements mainly in the form of buffer zones. In some cases, farmers also ensured wider safety distances to organically farming neighbors by the allocation of GM fields.

Inter-farm coordination always directly involves the adjacent farmers. We define four components of inter-farm coordination: (1) informing neighbors, (2) adjustment of cultivation plans, (3) use of different (maize) varieties and, finally, (4) cooperation. Cooperation itself can be divided into three subgroups, as suggested by Beckmann and Schleyer (2007), taking the possible forms of GMO-free zones, GMO zones, or cooperation for coexistence, for instance, in the exchange of plots to ensure safety requirements.

In most cases within our study, GM farmers informed at least directly-affected neighbors about their intention to plant Bt maize and about field location. This took place on a semi-official basis, since the actual GenTG did not require notification of neighbors at that time. However, notification was part of the Märka system in Brandenburg. We observed neither the adjustment of cultivation plans nor the use of different varieties and argue that inter-farm coordination is not generally necessary for the adjustment of cultivation plans. In northern Germany, maize cannot be drilled until late spring because of low soil temperatures. By then, winter grain (wheat, barley, rye, and rape seed) has already germinated. Thus, when it comes time for GM farmers to register in the cadastre, they have already been able to observe which crops have been sown next to their Bt maize stands and, consequently, can coordinate their planting without contacting neighbors.

The adjustment of varieties seems to be only a theoretical solution for coexistence. First of all, it is accompanied by additional costs, ranging from €46-201/ha (Messean et al., 2006). In Germany at present, only five different varieties of MON810 have been approved for commercial cultivation; two are medium-early varieties (DKC 3421 YG and PR 39V17), while three are late-maturing (Kuratus, PR 38F71 and PR 39F56) (Bundessortenamt, 2007). Based on this, we conclude that GM farmers can only vary the flowering time of their maize crops between these two groups, since no early-maturing varieties are yet available on the market, thus leaving little scope for inter-farm coordination. None of the farmers we interviewed took this form of coexistence into serious consideration.

The establishment of buffer zones or isolation distances can also create additional costs for the GM farmer, differing according to the width of the buffer zone and the size of the fields. The smaller the field, the higher are the costs for establishing a buffer zone (e.g., Messean et al., 2006). In certain areas, this can render cooperation for coexistence useful through exchanging plots to obtain larger fields. The average GM field size in our study was 36 ha; we therefore conclude that, in our cases, cooperation was not an incentive, because additional costs for buffering or isolation were not high enough. The results from our case study lead us to the overall conclusion that, under the given circumstances in Brandenburg, GM farmers tend to prefer intra-farm coordination rather than inter-farm coordination or even cooperation. This is mainly due to the existence there of large farms growing a still relatively low percentage of GM-maize, which appears to guarantee coexistence through intra-farm field coordination.

Role of Agribusiness and Local Seed Suppliers

We also analyzed how much the seed and grain trading company Märka has contributed to coexistence in Brandenburg. The GM farmers as well as most of their neighbors were well informed about the Märka system. However, in 2006 none of the adjacent farms made use of it. It should be noted that, in 2006, Märka was the only grain trading company in Germany which also took delivery of Bt maize harvests. In the case of coexistence, however, the impact of the Märka system should not be overstated because the system only applies to the production of grain maize that is brought to market, whereas most of the farms we interviewed focused on the production of silo maize. Secondly, in the case of grain maize production, the adjacent-farm maize must be below the labelling threshold to be bought by Märka as GM-free. Otherwise, the maize is exempt from this specific regulation and has to be labelled as GM. However, as orally reported from Märka, there was no price difference between Bt grain maize and conventional grain maize if quality parameters were comparable.

Thus, we come to the conclusion that Märka reduced liability costs not because it buys unlabelled neighboring grain maize, but rather because it pays the same prize for GM maize as it does for conventional maize (€120/ton in 2006). Gene outcrossing would thus not result in economic damage for neighboring conventional farms.

Conclusion

In the course of the interviews for this study it turned out that all of the GM farms in our sample were large. In Brandenburg, the average farm size is 200 ha (Ministry of Rural Development, Environment and Consumer Protection [Ministerium für ländliche Entwicklung, Umwelt und Verbraucherschutz], 2006). The area under agricultural production of the GM farms that we selected ranged from 500 ha up to 3,000 ha. In contrast, the ratios of GM maize in relation to overall farm sizes were still very small, since 2006 was the first year of [unrestricted] commercial GM cultivation in Germany. By arranging their GM fields, the GM farmers preferred intra-farm rather than inter-farm cooperation to guarantee coexistence. Furthermore, they used buffer zones and isolation distances and responded to their neighbors' concerns. Intra-farm coordination could be interpreted as a cost-effective manner of complying with ex-ante regulations and ex-post liability rules in force in 2006. Beyond this, perceived low additional costs of ex-ante regulation and ex-post liability are the reasons why cooperation was not necessary at the time. One could now assume that incentives for cooperation are thus more palpable in areas dominated by small-scale farms, as, for instance, in the federal state of Bavaria (Beckmann & Schleyer, 2007). However, at present hardly any Bt maize cultivation takes place there at all, even if it is affected by the ECB.

All interviewed GM farmers planned to expand their GM-maize production area. In the long run, this will probably render intra-farm coordination more expensive. However, GM maize will never account for 100% of the maize grown on these farms because measures for resistance management prescribed by seed producers foresee a percentage of at least 20% of non-GM maize (e.g., KWS SAAT AG, 2007). Theoretically, such refuge areas could as well be designed as a buffer zone, but this is not necessarily the case since they can also be located at a maximum distance of 750 m from the GM field.

Our analysis was carried out under the regulative framework of the GenTG of 2006. As stated above, this act neither defined specific distance requirements for Good Agricultural Practice, nor was there an obligation for GM growers to inform non-GM neighbors. The newly adopted regulation on GM crop production (GenTPflEV, 2008) now includes rigid ex-ante regulation: Minimum distance requirements for Bt maize are set at 150 m to conventional maize fields and 300 m to organic maize fields, though these requirements can be relaxed via private agreement. Beyond this, the GM farmer now has the duty to inform neighboring farmers on planned GM cultivation and is obliged to coordinate planting with neighbors.

Future adoption or rejection of Bt maize in Germany will strongly depend on the costs and benefits associated with this technology for farmers. A cost reduction will probably result in stronger adoption rates even for those farmers who are not heavily affected by the ECB. Yet, increasing costs of coexistence, for instance through rigid ex-ante regulations in combination with strict ex-post liability, as defined in the German regulation on GM crop production (GenTPflEV) and the GenTG, are likely to maintain rejection of this technology.

The 2009 planting season will give us the first evidence on the effects of the recently revised regulatory framework on the farm level, including whether farmers consider inter-farm cooperation for Bt maize cultivation to be a suitable option for reducing coexistence costs.

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