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The Costs of Coexistence on Farms in Germany

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In the European Union, freedom of choice between genetically modified (GM) and conventional or organic crops, for both producers and consumers, should be provided through coexistence measures. Coexistence measures at the farm level differ in costs and effectiveness and should not tip the balance for farmers in their cultivation decisions, and therefore it is important to measure these costs. In this article, we investigate the costs of different coexistence measures for farmers in Germany. Currently, GM crop cultivation is outlawed in Germany, but there was a short period from 2005-2008 when cultivation of Bt maize was allowed. We interviewed former Bt maize farmers and their neighbors concerning their experience with Bt maize cultivation and the costs of coexistence measures. The results show the clear differences in burden between the different measures. In addition, we show that there are important differences in farm characteristics and overall landscape configuration that influence the costs or burden of coexistence measures.

Key words: coexistence, *ex-ante* costs, *ex-post* costs, GM maize, regulation, Germany.

Introduction

The cultivation of genetically modified (GM) crops side by side with conventional and organic crops is a highly-contested topic in Europe. The basic starting point, from an EU point of view, however, is freedom of choice, both for the consumer and the farmer. In its recommendation on guidelines for coexistence, the European Commission has clearly stated that "in principle, farmers should be able to cultivate the types of agricultural crops they choose—be it GM crops, conventional, or organic crops" (European Commission, 2010, p. 4). In the same document, the European Commission also states that they want "to provide European consumers with a choice between GM and non-GM food" (*Ibid*., p. 4).

The flows of GM and non-GM products at the farmers' level allow for mixing at several steps in the cultivation process. Examples include incidental mixing between non-GM and GM seeds, pollen drift during cultivation, incidental mixing during the harvest, and volunteers after harvests. To minimize accidental mixing, additional measures can be taken during all steps of cultivation. These measures range from separate storage of seeds and harvest to minimum distances between GM and non-GM fields of the same crop and from the cleaning of machinery between harvests to a delay in seeding the GM crops to ensure asynchronous flowering.

Even when all feasible measures have been undertaken, adventitious presence of GM products in non-GM products can still occur. When such presence is detected, questions of liability arise. If the property rights lie with the non-GM farmer, then farmers planting GM crops may be held liable for ensuing economic damages. The magnitude of these damages for the GM farmer depend, among others, on i) what is to be done with the product after GM presence has been established, ii) whether a price premium is paid for non-GM products, and iii) the liability rules.

All the measures carry a cost, but there are important differences between the liability and the measures taken during the cultivation process. The costs of the measures during the cultivation are incurred *ex-ante* and known upfront. The liability costs, in contrast, are incurred *ex-post* and can, at the time of the decision to cultivate, only be estimated as expected costs (Beckmann, Soregaroli, & Wesseler, 2010).

If the policy objective is to ensure that farmers keep their freedom of choice, the costs of coexistence measures (both *ex-ante* and *ex-post*) should not tip over the balance when making the decision between GM crops and conventional crops, that is, the costs of coexistence should not be so burdensome that it becomes completely impossible to grow either GM or non-GM crops. Therefore, we need information on both costs and effectiveness of the different coexistence measures.

The effectiveness of different coexistence measures has been covered both at field level (Bückmann, Thiele, & Schiemann, 2016; Devos, Reheul, & De Schrijver, 2005; Foetzki et al., 2012; Hüsken & Dietz-Pfeilstetter, 2007; Nadal et al., 2016) and at landscape level with economic and ecological models (e.g., Ceddia, Bartlett, De Lucia, & Perrings, 2011; Colbach, Clermont-Dauphin, & Meynard, 2001; Groeneveld, Wesseler, & Berntsen, 2013) and with role-playing games combined with such models (Sausse, Le Bail, Lecroart, Remy, & Messéan, 2013). The general conclusions are that it is almost impossible to eliminate out-crossing completely, but that it can be reduced to a very low level and that common threshold levels can be reached without additional government intervention (Beckmann et al., 2011). The effectiveness of the different measures also depends on what is (not) considered to be a GM product. In the European Union, final consumer goods need to be labeled as GM if they contain more than 0.9% of a GM product (e.g., cornflour) or of a product that is derived from a GM product, such as soybean oil or sugar (EUR-Lex, 2008).

The actual costs of coexistence measures at farm level have received less attention so far. The measure that has received the largest share of attention is the minimum distance requirement. Several authors have shown that this measure can have a disproportional effect on the costs and implementation of coexistence (Beckmann et al., 2010; Demont et al., 2008; Devos, Dillen, & DeMont, 2014; Groeneveld et al., 2013). However, disruptive as it may be, the minimum distance requirement is not the only coexistence measure, and clustering and other coexistence measures have been applied as well. Skevas, Fevereiro, and Wesseler (2010), for instance, investigated the costs of five Bt farmers in Portugal and how they have reduced their costs by being members of a cooperative. They found that the costs of the measures taken are effectively zero because the farmers were able to coordinate the planting and location of the Bt maize. Consmüller, Beckmann, and Schleyer (2009) came to a similar conclusion after interviewing eight farmers in the federal state Brandenburg (Germany). However, coordination can be difficult due to, for example, free-riding incentives when compensation payments are required (Punt & Wesseler, 2017) and information issues (Sausse et al., 2013).

As part of the European research project PRICE (PRactical Implementation of Coexistence in Europe), we investigated the coexistence measures that were in place in Germany. The German federal authority allowed the cultivation of GM maize MON810 for a period of four years. Commercial cultivation started in 2005; however, not until one year later was the EU Regulation 2001/18/EU on the deliberate release of genetically modified organisms (GMOs) implemented into German national law and adopted to the German Genetic Engineering Act from 1990. Hence, 2006 was the first year of unrestricted commercial Bt maize cultivation in Germany (Consmüller et al., 2009).

In the first three years of commercial GM cultivation (from 2005 until 2007), the cultivation regulation standards in Germany were only good agricultural practice measures combined with strict liability rules. Since 2008, formal coexistence measures for Germany were implemented through the German Genetic Engineering Act. This act is further complemented by the best practice measures for GM crop cultivation and technical segregation detailed in the Genetic Engineering Plant Act and by the regulation on the implementation of the EU regulation on labeling and application of GMOs (Federal Ministry of Germany, 1990, 2004, 2008).

Farmers are obliged to enter planting information in the German location register of GM plants. The register is managed by the Federal Office of Consumer Protection and Food Safety (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit, BVL) to monitor the effects of GM crops and inform the public. Farmers also have to inquire about the necessary relevant coexistence measures at BVL. Two types of coexistence systems are in place—*ex-ante* regulation, with which GM adopters have to comply to ensure that the conventional or organic neighbors' field crop does not exceed the tolerance threshold, and *ex-post* liability to address the issue of liability in case of economic harm to the neighbor (Beckmann et al., 2006). The *ex-ante* and *ex-post* coexistence measures of the Genetic Engineering Plant Act, which are based on the EU guidelines, include the following.

Ex-ante regulation

- *Compulsory registration*: The operator who plants the GM crop (farmer) has to inform the Federal Office of Consumer Protection and Food Safety (BVL) three months before the intended GM plant seeding. The farmer has to provide information on the label and unique identifiers of the GMO product, its GM trait, the name and address of the person who cultivates the fields, the property of the cultivation, and the field size. Name and address are not published.
- *Minimum distance*: GM maize must be planted at least 150m away from conventional and 300m from organic maize fields. States have the right to implement their own minimum distance to conservation areas and so far, Brandenburg and Bavaria are the only federal states that requires keeping a minimum distance of 1,000m between a GM field and a con-

servation area (Bavarian State Government, 2011; Brandenburg State Government, 2016). Baden-Wuerttemberg also announced a minimum distance of more than 1,000m to conservation areas (Top Agrar Online, 2013).

- *Obligation to notify BVL and (since October 1, 2008) neighbors about the intention to cultivate genetically modified plants*: Neighbors are in this case owners of a field within the range of 300m of the GM field.
- *Private arrangements*: The Bt farmer can make an agreement with the neighbor up to three months before seeding to reduce the required minimum distance. The neighbor has to sign an admonition. If the neighbor does not answer the request within one month, the Bt farmer can reduce the minimum distance. The Bt farmer has to inform the BVL about the agreement.
- *The obligation to inquire information from the lower nature conservation authority (since October 1, 2008)*: The farmer has to inquire at the lower nature conservation authority (henceforth, local ranger) if any additional measures are required, due to nearby protected areas.
- *The obligation of documentation*: The GM farmer has to document the seed s/he uses and where s/he plants the GM plants. Additionally, the document must contain the cultivation technique and the occurrence of volunteers. Volunteers have to be destroyed.
- *Avoid commingling*: The farmer has to prevent GM seeding and GM harvest material from commingling with conventional material. Hence, the farmer has to clean all machinery that could potentially lead to an admixture.
- *Crop rotation*: Farmers must wait at least one year before cultivating conventional maize at a field if GM maize grew on that field before.

Ex-post liability measures

- In Germany, the GM farmer is fully liable if the GM cultivation causes any damage "…regardless of whether or not a direct link can be ascertained" (European Commission, 2009, p. 40).

This *ex-post* measure is known as strict liability and is based on the polluter-pays principle. If fields of more than one farmer are possible sources of the damage, all GM farmers are jointly liable (§32-4 GenTG, Federal Ministry of Germany, 1990). Potential damages are pecuniary injuries of the neighbor farmer if s/he has to sell the harvest at a lower price (Beckmann et al., 2006).

In 2009, Germany was the sixth country in Europe that banned the cultivation of MON810 maize varieties under the safeguard clause. Other countries using the safeguard clause are Austria, France, Greece, Hungary, and Luxembourg, while Italy refused to allow GM crop cultivation (Gaskell et al., 2010). Thus, currently no GM crops are commercially cultivated in Germany. However, the burden and costs of coexistence measures in Germany are still important topics should the government decide to allow cultivation again, and—in light of potential new products produced with new plant-breeding techniques—that may or may not fall under the EU directive 2001/18EC (EUR-Lex, 2015), as discussed in, for example, Hartung and Schiemann (2014) and Smart, Blum, and Wesseler (2015).

In this article, we assess the perceived burden of the prescribed coexistence measures on a Likert scale and in terms of time and cost by farmers in Germany. The same survey was carried out in four other European countries—Spain, Portugal, Romania, and the United Kingdom. Tillie, Dillen, and Rodríguez-Cerezo (2016) compared the different countries in terms of perceived burden on a Likert scale. They found that farmers dislike administrative and coordination measures and do not mind technical measures. A more in-depth analysis of the survey from the United Kingdom can be found in Jones and Tranter (2014). Kalaitzandonakes and Magnier (2016) carried out a survey among GM and non-GM farmers in the United States, where coexistence is managed on a voluntary basis. They found that farmers perceive coexistence in its current state not a restriction to cultivate non-GM crops.

Although a similar German case study was carried out by Consmüller et al. (2009), we focus on the whole of Germany instead of one federal state; as such, our population and sample are larger. Venus, Dillen, Punt, and Wesseler (2017) investigated the choice experiment of the same dataset and use it to calculate perceived costs for some of the measures. In the current article, we investigate other cost aspects of the measures in more detail—the individual ranking of the measures by the farmers and the estimated time needed for the respective measures. Moreover, we investigate a wider range of coexistence measures, as the number of measures in the choice experiment was restricted to four to prevent an information overload.

We interviewed farmers that have grown Bt maize in the past as well as their neighbors and some other farmers from the same area. In the interview, we asked them to report the general burden of a measure, the time taken to implement it, and their own estimate of the direct cost of the measure. This information allows us to give a more detailed estimate of the costs of measures in addition to how it is influenced by, for example, farm characteristics. We thus contribute to the literature by giving detailed estimates of several coexistence measures that have received less attention so far.

In line with Venus et al. (2017), we find that the isolation distances are not the most burdensome measure, at least, as assessed by these farmers. In their view, liability, having to wait two years to plant conventional crops on former GM fields, and requesting permission from the government are more important.

Materials and Methods

In May 2012, we approached all known 91 former Bt maize farmers in Germany with a request to participate in a face-to-face interview through the BVL. If the farmer agreed, they were asked to send a response card to us with their address, as well as the addresses of potentially interested neighbors. Two of the 91 letters returned to the BVL because the address was wrong or the recipient was unknown. 34 farmers answered the letter, and 54 did not. Of all farmers who replied, 24 farmers agreed to the survey and 11 declined. Reasons for declining the survey were

- "cultivation and coexistence are currently not relevant for agriculture,"
- "politicians haven't made up their mind and it is consequently too risky to cultivate GMOs,"
- "fed up with the ban by the politicians,"
- "had trouble in the first year. Yield was 20% extra, though,"
- "just testing reactions,"
- "not interested,"
- "only trials, no real cultivation,"
- "was criminalized by neighbors," and
- "was forbidden by the landowner to grow GM."

Two did not give any reason. From the 24 who agreed in the first place, four either changed their mind to participate in the survey or they did not have time for the survey. An organization called InnoPlanta[1] where all Bt farmers are registered tried additionally to contact five of the farmers who did not reply to the BVL letter. Four agreed, and one declined to participate in the survey because he had problems with his landowners and did not want to be further connected with GM-crop-related activities. The interviewed Bt farmers additionally named seven Bt neighbor farmers who also did not reply to the BVL letter. Three of the neighbors agreed to participate and four declined. Reasons for declining were

- "invested much money in Bt maize production and much of it was destroyed by GMO-opponents,"
- "chairmen who was responsible for GMO production retired," and
- "no time for a survey."

Overall, 42 farms who did not reply to the letter remained unknown.

To get the contact data of neighboring non-Bt farmers, the Bt farmers were asked if they would provide this information. The 27 Bt farmers provided the contact data of 53 non-Bt neighbors. All of the neighbors received a request by phone to participate in the survey. In total 20 neighbors agreed to participate. The main reasons for rejection were

- "no time,"
- "no interest on the topic,"
- "do not plant maize,"
- "area is leased out,"
- "responsible person is retired/sick/died."

In total, 27 Bt and 20 non-Bt farmers participated in the survey.

Farmers were interviewed in two rounds—one in November 2012 and one in March 2013. Farmers were asked for their general knowledge, attitudes and perceptions towards GM crops and other new technologies, socioeconomic and farm characteristics, relation with neighbors, their experience with GM maize, and the burden of coexistence measures. The questionnaire also contained the choice experiment mentioned earlier.

An inherent difficulty with the data is that the experience with these coexistence measures and the cultivation of the Bt maize lies typically 4-5 years in the past. Therefore, the data is subject to recall bias. To mitigate this bias, we asked a number of questions about farmers' maize cultivation in 2008 to reactivate their memory about that time, but these variables are not used in the analysis of the actual coexistence measures themselves.

1. InnoPlanta e.V. is a registered association that has officially the objective to promote agro-biotechnological and modern plant breeding activities of farmers, companies, scientific institutions, and others and to provide a network for them (Innoplanta e.V., n.d.).

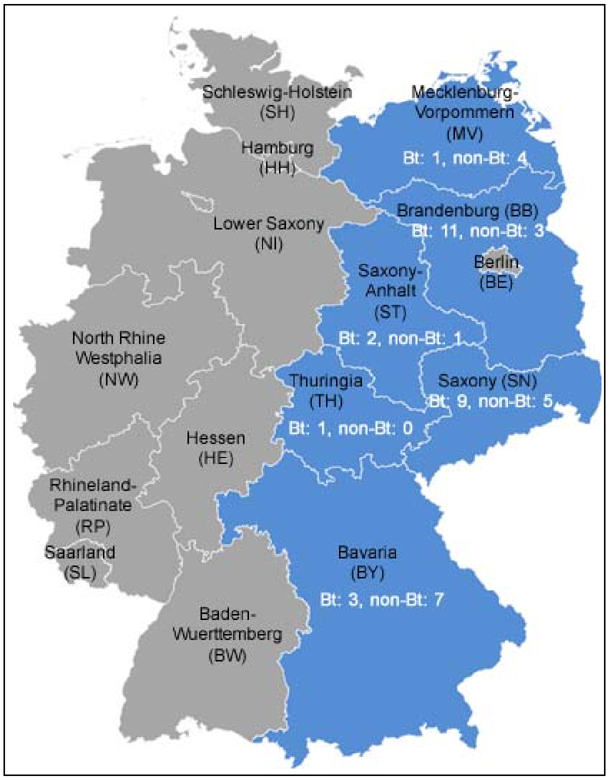

Figure 1. Study regions with the number of Bt and neighborhood non-Bt respondents.

Source: Own design, Map from: www.stallwanger.net

In addition, we explicitly asked farmers for estimates in terms of burden, time, and costs of coexistence measures should they implement them now, not for an estimate of the burden, time, and cost they had experienced. Finally, Bradburn, Sudman, and Wansink (2004) reported that recall is better for less salient events, and these coexistence measures were unusual because they are not part of standard farming practice. However, we cannot exclude the possibility of recall bias when farmers make these estimates, and as such our results should be interpreted with care.

During 2005 and 2008, farmers from 12 of 16 German federal states registered a Bt maize cultivation area with an increase in each of the three years after its commercialization. Cultivation reached a maximum in the last year before the ban with a total area of 3,171 hectares or 0.15% of the total maize production area in Germany. More than 92% of the Bt maize area was located in only three federal states—Brandenburg (39%), Saxony (30%), and Mecklenburg-Western Pomerania (24%). As such our sample is located in the federal states—Bavaria (*n*=10), Brandenburg (*n*=14), Mecklenburg-Western Pomerania (*n*=5), Saxony (*n*=14), Saxony-Anhalt (*n*=3), and Thuringia (*n*=1). Consequently, we do not have a representative sample for the whole of Germany (see Figure 1).

Table 1. Summary statistics for sample farms and farm population.

Characteristic	Sample statistic[1]	Population statistic in 2010[2]	Population statistic in samples states in 2010[2]
Age (years)	51 (11)	50.1[3]	50.8 [3]
Job experience (years)	31 (13)	-	-
Farm size (ha)	1147 (897)	55.8	70.95
Farm size juristic farms (ha)[4]	1418.4 (818.8)	630.7	
Farm size single farms (ha)[5]	144.2 (116.4)	43.9	
Land rented	65%	59,8%	69.95%
People employed on farm (No.)	22 (21)	3.61	3.30
Number of neighbors (No.)	14.0 (18.1)	-	-
Farm income/ profit[6]	€82,000	-	-
Area maize (ha)	219 (209)	-	-

The number in parenthesis is the standard deviation.

[1] Source: author's survey

[2] Federal statistical office (2011)

[3] Calculated from the age structure by multiplying the median from each class with its share

[4] n(Bt farms) = 24, n(non-Bt farms) = 13

[5] n(Bt farms) = 3, n(non-Bt farms) = 7

[6] Some farmers reported farm income and others reported profit, calculated by taking the share of number farms multiplied by the median of each class.

Results

Sample Description

The summary statistics, as well as averages for Germany and the federal states that we sampled, are reported in Table 1. A comparison between the sample means and the means of Germany and the sampled federal states reveals that our sample consists of relatively large farms, both in size and number of employees, even by the standards of the federal states considered. This result can be explained at least partly by the fact that we sampled mainly farm companies and cooperatives. For example, when we exclude the sole proprietorship farms from the mean in the sampled federal states the average farm size increases from 70.95 to 508.4 ha and the num-

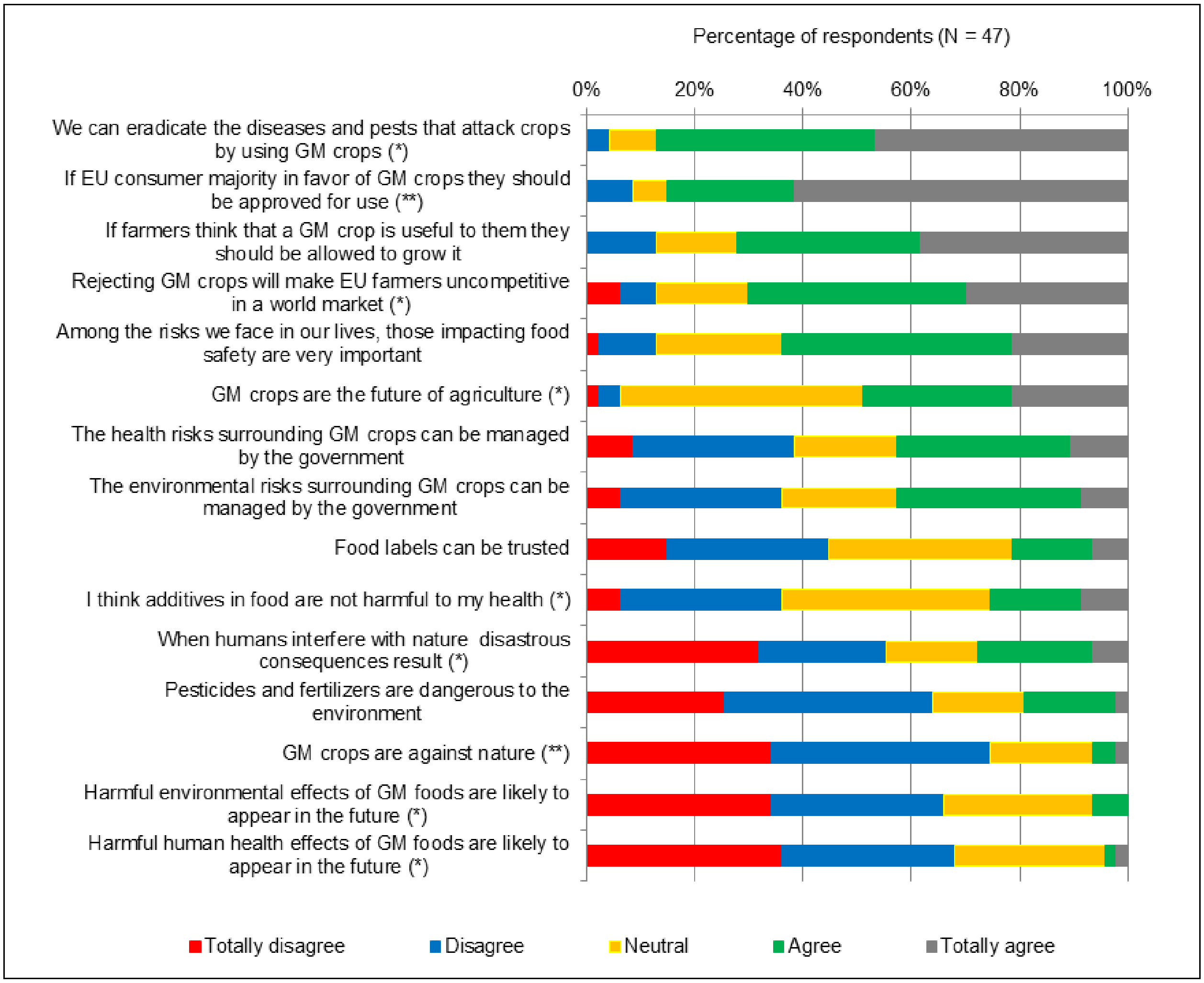

Figure 2. Attitude of farmers.

The scale runs from totally disagree to totally agree.

** Significantly different distribution of Bt and non-Bt farmers (Fisher's exact test, 5% significance level)*

*** Highly significantly different distribution of Bt and non-Bt farmers (Fisher's exact test, 1% significance level)*

ber of people employed increases from 3.3 to 13.5, which is still below our sample mean but closer than the population statistic or the population statistic in the sample states (Federal Statistics Office, 2011). The main farm type in our sample was a mixed farm type (80%), with a focus on either milk (44% of total) or cereal production (40% of total), and, as can be expected of large farms, the farm income was relatively high: 75% of the sampled farmers reported an income over €60,000 and 45% of them reported an income of more than €100,000. The level of education was also high: 45% attended a university of applied sciences and 32% an agricultural university.

Comparing the Bt and non-Bt farms, we find little differences in the descriptive statistics. Using a Wilcoxon rank-sum test we only find significant differences at the 10% level for the mean age and number of employees. The tests indicate that Bt farmers were on average older than their neighbors, and they have a few more employees. This indicates that the reasons for cultivating GM maize within the sample are not driven by farm characteristics and must consequently be sought in other grounds.

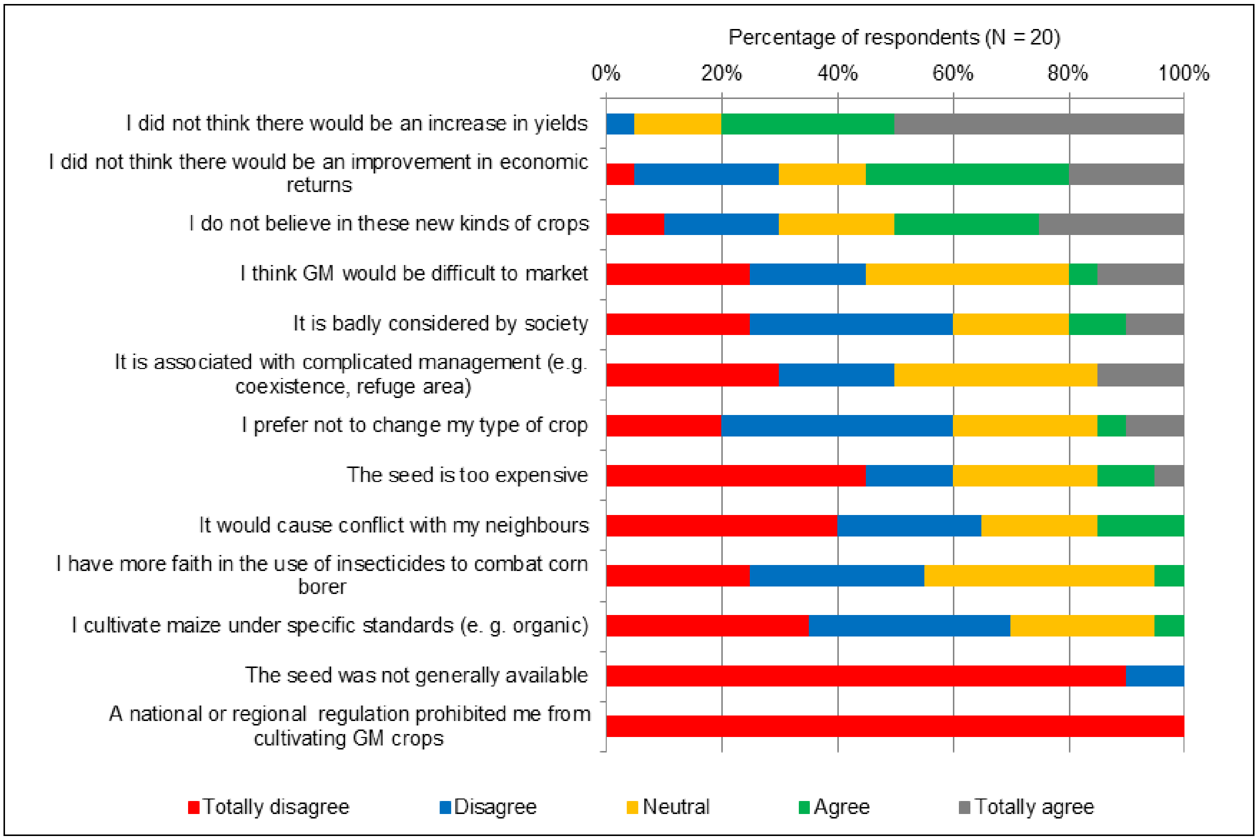

Figure 3. Non-GM farmers' reasons for not adopting Bt maize.
The scale runs from totally disagree to totally agree.

Cultivation of GM and Conventional Maize

We consider attitudes to be an important possible driver for the decision to adopt GM maize, or more generally, a new technology. Therefore, we tested farmers' attitudes with a Likert scale. When comparing the attitudes toward GM crops and new technologies in general, a difference can be observed between GM and non-GM farmers, although the opinions of the farmers tend to go in the same directions (see Figure 2).

Using a Fisher exact test, we find that the farmers disagree on nine statements and agree on six (at 5% significance level). The statements on which they disagree are all statements concerning GM crops, except for the statements regarding risk management by the government, which is another source of disagreement.

As the only cultivated GM crop in Germany was Bt maize, we asked the farmers detailed questions about their cultivation of maize in 2008, the last year that they were allowed to cultivate GM crops. We asked how much maize they cultivated in 2008, what types of maize they cultivated (i.e., silage or grain maize), and whether they sold the maize or kept it for on-farm use.

For GM farmers, we distinguished between GM maize and conventional maize. GM maize farmers were asked whether they had observed any differences between the GM maize and the conventional varieties. Farmers that had not cultivated GM maize were asked to make an estimate of how their harvest, gross margins, and selling prices would change if they had used GM maize. In addition, these farmers were asked why they opted not to grow GM maize. Reasons were ranked on a scale from 1 to 5. Farmers could also supply their own reasons: two farmers named landowner's consent as a reason and one farmer indicated it was the dependency on the seed industry. As can be seen in Figure 3, the main reason (besides economic ones) were societal reasons and—to a certain extent—the difficulty in marketing. This can also be observed in the follow-up questions: 60% of the conventional farmers expected a zero-price difference between GM and non-GM maize, and 10% a slightly lower price for GM maize, remarking that it could be difficult to sell. In contrast, conventional farmers expected an increase in harvest of, on average,

Table 2. Means of the cultivated area per maize type by farmer group in 2008 in hectares (ha).

		GM farmers			
Variable	**All farmers**	**Bt**	**Conv.**	**Total**	**Conventional farmers**
Total maize area	195 (198)	44 (47)	166 (153)	209 (84)	176 (218)
Grain maize area	38 (72)	21 (16)	97 (105)	89 (99)	69 (40)
Silage maize area	158 (174)	51 (52)	166 (115)	201 (151)	159 (197)

The number in parenthesis is the standard deviation.

9.25% and an average increased gross margin of €34 per hectare if they would use Bt maize.

The main maize type cultivated in the sample was silage maize, which was cultivated by 87% of all farmers; only 45% cultivated grain maize. There are differences between the GM farmers and the conventional farmers: 66% of the GM farmers grew silage maize, whereas all conventional farmers cultivated silage maize. Also, 48% of the GM farmers grew grain maize, whereas only 25% of the conventional farmers cultivated grain maize. Further details on the maize area grown in 2008 by all farmers and the different groups are shown in Table 2. As can be seen from the table, most of the GM farmers only used a limited area of Bt maize (roughly 25%); the main part of their production still consisted of conventional varieties.

Moreover, the total area of maize cultivated, of any type, by the GM farmers lies consistently above the total area cultivated by conventional farmers. A t-test, however, neither reveals significant differences between GM and conventional farmers in terms of mean of the total area of maize cultivated, nor differences in the means of cultivated area per maize type (p>0.1).

Coexistence Measures

Farmers that had cultivated Bt maize in the past received a questionnaire that was slightly different from the one used for their neighbors. As we were interested in the actual experience with coexistence measures, we asked the farmers to only answer those questions regarding measures with which they had experience. Consequently, neighbors were only asked about the coexistence measure where they had to reply to their GM neighbor. GM farmers were asked about their experience with informing their neighbors, informing the local government for nature conservation purposes, getting registered in a public registry, liability for incurred damages of non-GM farmers, minimum distances of 150 to conventional and 300 meters to organic farmers, getting permission from the government, separation of GM and non-GM seed and harvest, cleaning of machinery, five-year checking for volunteers, five-year record keeping and waiting with conventional maize on the same field for two years. All farmers were asked regarding the coexistence measures to rank the burden of each measure on a scale from 1 to 5, and to give an estimate of the incurred time and costs for each measure. Farmers could also indicate non-obligatory measurements that they had taken themselves to reduce the risks of adventitious presence. The stated measures were often mixes of a small number of other measures, such as personal dialogues with neighbors (8 times), sowing of buffer conventional strips (5 times), covering the harvest transporter with a tarpaulin (1 time), and an article in the local newspaper (1 time).

Even though we asked farmers that had experience with these coexistence measures, they often indicated that they did not know what a measure had cost them, neither in terms of time nor in €/ha. Therefore, we can only explore a limited number of these measures in more detail. We had sufficient data—that is, more than 20 observations—only for the time spent on informing neighbors, informing the local ranger, and registering in the local registry. We assumed a linear relationship between the independent and dependent variables. Since the number of observations is limited we can only include a limited number of explaining variables, which we tried in several combinations to test the robustness of the model. For time spent talking to neighbors, we included farm size, the number of neighbors, and their interaction. For the time spent on registering and informing the local ranger, we investigated a linear relationship with farm size and percentage of planted maize that was GM.

Finally, most farmers did report the burden for all measures we investigated. A Likert measure, however, is unsuitable for a normal ordinary least squares regression, as it is an ordinal measure. Therefore, we decided to investigate whether the three most burdensome coexistence measures as indicated by the farmers—liability, requesting government permission, and having to wait two years—correlated strongly with farm size and percent of area used for maize or GM maize. We also investigated isolation distances of 150 meters, as they are

Table 3. Mean burden, time, and cost incurred per coexistence measure.

Coexistence measure	Burden	Time (minutes/year)	Costs (€/ha)
Inform the neighbors 3 months in advance	2.5 (1.4)	374 (782)	12 (33)
Clarify potential conflict regarding nature reserves with the local ranger	2.6 (1.5)	318 (837)	8 (13)
Register in a public registry	2.1 (1.3)	573 (2,349)	4 (8)
Liability for damages to non-GM farmers	2.8 (2)	364 (772)	1 (2)
Minimum distance of 150 meters to neighbor's conventional maize fields	2.2 (1.3)	205 (319)	1 (3)
Minimum distance of 300 meters to neighbor's organic maize fields	2.3 (1.5)	301 (633)	6 (15)
Request permission from the government	3.1 (1.7)	307 (703)	2 (3)
Store seeds of GM and conventional varieties separately	2.1 (1.3)	44 (53)	1 (3)
Store harvest with reproductive capacity of GM plants separately	2.5 (1.6)	158 (282)	4 (7)
Clean machinery after use on GM fields	2.7 (1.4)	482 (686)	21 (41)
Check for volunteers one year after growing GM plants	1.7 (1.1)	155 (287)	4 (9)
Keep records of cultivation for five years	1.9 (1.3)	1,143 (2760)	7 (14)
Wait 2 years with growing conventional varieties on a former GM planted field	3.2 (1.7)	111,707 (333,113)	131 (351)
Responding to the GM farmer (conventional farmers only)	1.4 (1)	27 (41)	20 (45)

The number in parentheses is the standard deviation.

Table 4. Regression results of the measure informing the neighbors.

		Effects				
Coexistence measure	**Model**	**Intercept**	**Number of neighbors (*N*)**	**Farm size (*S* in ha)**	**Interaction (*N**S*)**	**Adjusted R^2**
Informing neighbor 3 months in advance (*T* in minutes per year)	$T = ß_0+ß_1*N$	128 (53)*	7.5 (2.1)**	-	-	0.33
	$T = ß_0+ß_1*S$	199 (92)*	-	0.02 (0.05)	-	-0.03
	$T = ß_0+ß_1*N+ß_2*S$	33 (92)	8.2 (2.2)**	0.06 (0.05)	-	0.35
	$T = ß_0+ß_1*N+ß_2*S+ß_3*N*S$	-36 (87)	14 (3.1)***	0.21 (0.07)**	-0.01 (0.005)*	0.48

The number in parentheses is the standard error.
, **, * denotes p<0.05, p<0.01, and p<0.001, respectively.*

often studied in the literature. The correlations will at least give us some information on how these measures are affected by other variables.

Exploratory Statistics

As can be seen from Table 3, most of the coexistence measures were ranked as being not so burdensome. The least convenient measures include having to wait for two years with planting conventional varieties and requesting permission from the government, but even those measures are only slightly above three. Time and cost estimates show a slightly different pattern in the sense that the overall ranking of measures is slightly different. Using a Spearman ranking test on the measures for GM farmers we find the following correlation coefficients: ρ (burden-time) = 0.30 (p=0.21), ρ (time-costs) = 0.60 (p=0.01), and ρ(burden-costs) = 0.18 (p=0.55), where p is the probability that ρ is not significantly different from zero. This indicates that there is a relatively strong correlation between time and costs, as expected, but not so much between burden and time or burden and costs. A possible explanation is that some of these measures have to be carried out independently of Bt maize cultivation, and that the estimated time and costs are therefore not additional time and costs that have to be incurred when a farmer decides to cultivate GM crops. Record keeping is a case in point. Another reason is the different scales because the burden is an ordinal rather than a cardinal scale.

Table 5. Correlation (Kendall's ranking test) between burden of coexistence measures and several farm and maize characteristics.

	Isolation distance 150m	Liability	Requesting government permission	Waiting for 2 years
Farm size	-0.26°	0.07	0.06	-0.39*
% GM maize planted	-0.12	-0.07	0.29	0.14
% area maize	0.20	-0.31°	-0.19	0.03

*° denotes significance at p<0.1, * denotes significance at p<0.05*

Regression Analysis of Time Variables

The results of the regression analysis of informing the neighbors are displayed in Table 4. One outlier was removed to obtain these results. The outlier was a farmer that had very unpleasant experiences with his neighbors during the time he planted GM crops. As such, he estimated the required time he would need roughly four times higher than the next highest time required and roughly ten times more than the sample mean. As expected, the main factor that drives up the required time is the number of neighbors. One additional neighbor drives up the required time by 7.5-14 minutes per year, depending on the model specification. Farm size is often mentioned as an important variable in the analysis of coexistence measures. A larger farm means, on the one hand, more neighbors, an indirect effect; on the other hand, it may be easier to allocate GM crops such that neighbors do not have to be informed. Neither of these effects is very clear from our regression results. The effect of size is not significant except when combined with an interaction term with neighbors. The effect is always positive, suggesting that the indirect effect dominates the direct effect. The negative sign of the interaction effect is unexpected. A possible explanation is that large farmers benefit from economies of scale. If there are many neighbors, they can inform them, for example, by a large mailing rather than visiting all neighbors personally.

We investigated several combinations explaining the variable time required for registration with farm size and percentage of GM maize planted, as well as explaining the time required for informing the local ranger with these variables, hypothesizing that farm size and percentage of GM maize planted would increase the time needed as more data would be required. We found no significant effects. Unfortunately, we have no other relevant variables that may explain the required time any further.

Correlation of Burden of Selected Coexistence Measures with Farm Size and Maize Characteristics

We checked the correlation of the burden ranking of several coexistence measures with farm size, the percentage of farm size used for maize, and percentage of planted GM maize. Our hypothesis was that larger farms would have more flexibility in allocating land and have more financial resources, and as such find these measures less burdensome. In contrast, having relatively more maize—as well as having relatively more GM maize—should imply that more care has to be taken and should increase the burden of these measures. We restricted our attention to the measures that were ranked on average as most burdensome by the farmers, i.e., liability, requesting government permission, and waiting for two years. We also included isolation distance, as it is often studied in the literature.

Concerning isolation distances, we do indeed find a positive correlation, but only significant at a 10% level (Table 5). There is no obvious effect of the percentage of GM maize planted on the perceived coexistence burden, nor is there an effect of the relative percentage of maize planted. For liability, we found a small effect of relative maize area at 10% level, indicating that liability burden goes down if relative maize area goes up. A possible explanation is that with an increasing acreage of total maize, the risk of outcrossing with neighbors becomes less. For requesting government permission, we did not find any significant effects. Finally, waiting for two years to cultivate conventional maize on former GM maize fields is indeed less burdensome for larger farms, possibly because they have greater flexibility in land allocation.

Discussion and Conclusions

In this article, we assessed the costs of different coexistence measures that were implemented in Germany during the short period that GM cultivation was allowed (2005-2008). We interviewed 27 former GM farmers and 20 of their neighbors and asked them to assess the burden, time, and costs of the different coexistence measures they implemented. We also asked them for other strategies they used which were not part of the formal legislation in Germany. Most of the farmers reported that in addition they used buffer zones of conventional maize around the GM maize and entered into personal dialogues with their neighbors.

We found that farmers ranked liability, having to wait two years to cultivate conventional crops on former GM fields, and requesting government permission to cultivate GM crops as the most burdensome. The burden ranking, however, did not always coincide with the expected time required for measures or the implied costs. A possible reason may be that some measures such as record keeping have to be implemented independently of Bt maize cultivation, and as such do not take much additional time.

As farm size is deemed an important proxy for flexibility of the farmer, we checked whether the measures that bothered the farmer decreased with farm size. We did indeed find a negative correlation between farm size and the measure of having to wait. A similar effect was observed for the burden of isolation distances of 150 meters. This implies that indeed larger farms have an advantage implementing these measures—at least, they find them less burdensome. However, we found no significant effects of farm size on the other measures that farmers also found burdensome, and neither was there an effect of farm size on the time spent for informing the local ranger or registering in the public registry. Therefore, larger farms do not necessarily have an advantage for all coexistence measures.

Concerning time spent on informing the neighbors, two things clearly stand out from the results. Unsurprisingly, the amount of time required depends on the number of neighbors. There is also an effect of farm size, but it is not as outspoken as the neighbor effect. The correlation between farm size and number of neighbors was not significantly different from zero, implying that they do indeed measure different things. This suggests that for neighbors much depends on the configuration of the fields rather than the absolute field size. Moreover, as our removed outlier suggested, the time required can be severely magnified if the local community is against the cultivation of GM crops.

These results, of course, have to be seen in the light of our small dataset. Such a dataset only allows us to find the strong effects. Several smaller effects that were not detected may be at work. As the population is so small, however, it will be hard to increase the sample size of former GM farmers in Germany.

The overall conclusion of this article is that the different coexistence measures have differing costs and that various factors drive these costs. Although farm size may play a major role for some coexistence measures, its effect seems to be less pronounced for other measures. This suggests that when we formulate the measures that are supposed to be part of our coexistence regime, and we want a freedom of choice for all parties involved, we should pay close attention to the local situation.

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