THE ADOPTION OF BT-MAIZE IN GERMANY: AN ECONOMETRIC ANALYSIS

Consmüller, Nicola; Beckmann, Volker and Petrick, Martin

nicola.consmueller@agrar.hu-berlin.de

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Abstract

In this study, we theoretically and empirically investigate the determinants of Bt-maize adoption in German regions. Specifically, we ask how the regulatory framework, the farm structures as well as the socio-political environment of GM expansion in Germany have influenced regional adoption rates. Following a description of the relevant legal and economic framework in Germany, we develop theoretical hypotheses concerning regional variation in Bt-maize adoption and test them econometrically with unique data at the Federal States (Länder) and County (Landkreis) level. The study provides evidence that the adoption of Bt-maize in different regions is positively affected by the amount of maize grown per farm and by the European Corn Borer (ECB) infestation rates. There is also some evidence that the Bt-maize adoption is negatively affected by the activities of the anti-GMO movement and the establishment of GMO-free zones.

GMO crops, Germany, panel data analysis

1 Introduction

Since 2005 Bt-maize resistant to ECB (European Corn Borer, *Ostrinia nubilalis* HÜBNER) has been allowed for commercial cultivation in Germany. Subsequently, adoption has been picking up in the East German Federal States, notably in Brandenburg, Mecklenburg-Western Pomerania, Saxony, and Saxony-Anhalt. These are dominated by large farm structures and are among the least densely populated areas of Germany. Although ECB infestation is reported to be a serious problem in the southern parts of Germany as well (e.g. Bavaria and Baden-Württemberg), Bt-maize adoption rates have been much lower there, rarely exceeding 10 ha per State (BVL, 2008). At the same time, public controversy concerning the principal desirability of genetically modified (GM) crops in German agriculture has gained new momentum, including partially violent destruction of fields sown with Bt-maize by members of anti-GM movements. These opponents argue that GM crop production may pose unpredictable risks to human health and the environment, and that the technology may favour undesirable farming structures and practices (www.gentechnikfreie-regionen.de).

Based on two regional panel data sets, we analyse the determinants of varying adoption rates in Germany. Given the paucity of rigorous analysis of Bt-maize adoption in Europe, it is the first systematic study that analyses the influence of structural and political determinants of adoption in a multiannual setting. Following a description of the relevant legal and economic framework in Germany in the second section, we develop theoretical hypotheses concerning regional variation in Bt-maize adoption in the third section. The econometric methodology to test them with unique data at the State (Länder) and County (Landkreis) level is developed in the fourth section. The fifth section presents the results and the final section concludes.

2 Legal framework for growing Bt-maize in Germany

Following the EU legislation (2001/18/EC, 1829/2003, 1830/2003 and 2003/556/EC), Germany incorporated rules of ex-ante regulation such as a general code of Good Agricultural Practice (GAP) as well as the creation of a public site register and ex-post liability rules (joint and several liability) into the German Genetic Engineering Act (GenTG) in 2004, coming into force in January 2005. During the first three years of commercial cultivation (2005 until 2007), the German Genetic Engineering Act (GenTG) combined rather flexible ex-ante regulations with strict liability rules because concrete and scientifically based safety measures to keep cross-pollination of maize below the labelling threshold of 0.9% were not agreed upon yet (GENTG 2006). This legal gap was initially filled by recommendations of the seed industry which suggested the installation of 20 m conventional hybrid maize buffer zones around Bt-maize fields. However, during the first years little experience existed regarding the possible risk of outcrossing, the risk of economic damages and finally the risk of being held liable. Thus, the fist years were characterised by high uncertainty and little practical experience.

In 2008, isolation distances for GM maize of 150 m and 300 m respectively were defined by the new regulation on GM crop production (Gentechnik-Pflanzenerzeugungsverordnung, GenTPflEV), which are, however, not relevant for our data analysis. However, as a matter of flexibility, the new GenTG allows farmer to enter into private arrangements to reduce the minimum distance requirements. All additional costs of ex-ante regulations and ex-post liability which emerge from the GenTG have to be carried by the GM farmer exclusively. This includes field registration in a national cadastre, compliance with security measures, and liability in case of damage (CONSMÜLLER ET AL., 2008). Only the costs of testing for GM presence have to be borne by the non-GM farmer.

3 Determinants of Bt-maize cultivation

Against the regulatory background for GM crop cultivation in Germany and the significance of the anti-GM movement as well as from literature review we hypothesise that a number of factors affect the benefits and costs of Bt-maize adoption such as the ECB infestation rates, the maize area cultivated per farm, the ownership rights in land, the importance of organic farms in a region, the share of GM-free regions and the strength of the anti-GM activists and finally time (BECKMANN AND WESSELER, 2007; BECKMANN ET AL., 2006). While some have been discussed in the literature, several others have not been considered in adoption research so far:

3.1. ECB infestation rates

From a farm management perspective, potential infestation with ECB should be the prime reason for the adoption of Bt-maize. Resistance against this pest is the single benefit of this maize variety and the profitability of Bt-maize adoption is crucially determined by the opportunity costs of doing so. High adoption rates are therefore to be expected in those regions where ECB has been a recurrent problem. Literature on the adoption of Bt-maize in the U.S. reveals that the cultivation is confined to those areas with heavy infestation rates of the ECB. We assume that this also applies to Germany where high pest incidence is reported from the Oderbruch region in Brandenburg (SCHRÖDER ET AL., 2007) and parts of Baden-Württemberg and Bavaria (DEGENHARDT ET AL., 2003). To test the effect of ECB infestation rates, meaningful data on economically relevant infestation rates is required. One plausible measure is the frequency of infestation because it depicts the heaviness of infestation in terms of the percentage of infested plants and thus the need for the farmer to take action according to the economic threshold. Unfortunately, corresponding data for Germany is unavailable at the Federal States level. We therefore had to confine our analysis to counties in Brandenburg, for which this data was collected for the years 2005 to 2007 and published by the LVLF (Landesamt für Verbraucherschutz, Landwirtschaft und Flurneuordnung).

3.2. Maize acreage per farm

Assuming that ECB infestation is a recurring problem, the second important factor affecting the economic benefits of adopting Bt-maize is the amount of maize planted on a farm. Since Bt-maize is an embodied technology, viz. incorporated in the new product, the economic benefits of Bt-maize increase with the extent of maize cultivation. The incremental benefits of growing Bt-maize compared to the untreated control are estimated up to 93 € per ha (DEGENHARDT ET AL. 2003)[1]. Thus without considering the costs of the regulatory environment and assuming a constant infestation, the benefits would increase linearly with the area of maize cultivated on the farm. In this case, the Bt-technology would be scale neutral, but the overall incentives to adopt Bt-maize would increase with the size of maize acreage per farm. However, ex-ante regulations and ex-post liability of coexistence introduce additional costs, some of which may have a fixed cost character (BECKMANN AND WESSELER 2007). MESSEAN ET AL. (2006) report additional on-farm costs for creating buffer zones of between 60 and 78 € per ha depending on the size of the Bt-maize field, the width of the buffer zone and the adoption rate of Bt-maize in the region. The authors further note that the smaller the GM fields the higher the on-farm costs per ha caused by the establishment of buffer zones. Until the recent amendment of the German Genetic Engineering Act in 2008, best management practices for the cultivation of Bt-maize were defined as 'all measures to reduce the probability of cross-pollination' (e.g. buffer zones, safety distances etc., GenTG, 2006) and buffer zones of 20 m were the most common measure to facilitate coexistence. However, the installation of buffer zones or safety distances requires a certain amount of cultivation area depending on the required width. In the case of a 20 m buffer zone, this theoretically means that for planting only 1 ha of Bt-maize, a field of nearly 2 ha in total will be needed (see Figure 1).

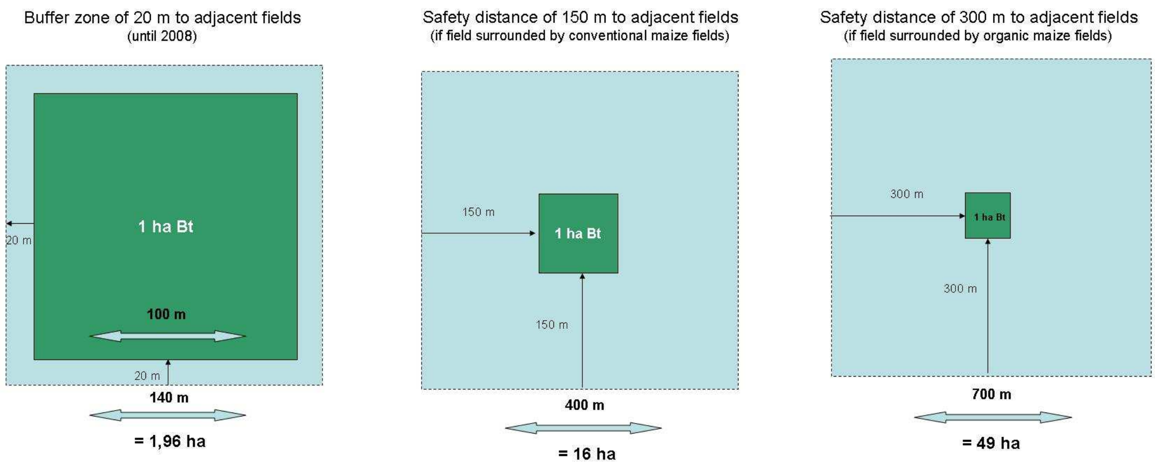

Figure 1: Requirements for total field size according to different safety distances

Recent legal restrictions (the GenTPflEV 2008) have tightened these requirements even more. Minimum distance is set at 150 m to conventionally and 300 m to organically cultivated adjacent fields. For planting 1 ha of Bt-maize the minimum necessary field size will hence increase up to 16 and 49 ha, respectively. Bt-maize adoption is thus strongly dependent on the

[1] Brooks (2007) has reviewed the gross margin for several European countries. In Spain, gross margin benefits of growing Bt-maize were estimated between 67 and 330 € per ha; in France between 98 and 120 € per ha.

possibility to create large maize fields. While regulations before 2008 were less strict, this factor will gain importance in the future. Besides the buffer zones and the minimum distance requirements, the ex-ante regulation may also include fixed costs, such as the registration of Bt-plantation in the public site register and informing neighbours.

Summing up, the ex-ante regulation and ex-post liability rules introduced in Germany turn a size neutral technology into a size dependent one, leading to the hypothesis that larger farms or more precisely farms that plant more maize are more likely to adopt, given that maize is subjected to ECB infestation. The influence of the farm size on the adoption of GM crops has been discussed intensively by FERNANDEZ-CORNEJO AND MCBRIDE, 2002, GÓMEZ-BARBERO ET AL., 2008 and some of these authors also report a significant influence of the actual farm size on the adoption of Bt-maize.

3.3. Ownership rights

Farmers interested in Bt-maize adoption face another potential obstacle if they are not the owner of their land. There are recent attempts of landlords to prohibit the cultivation of Bt-maize, because they fear liability claims in case of cross-pollination or a long term negative side effects on their property. Beyond this, many municipalities have already banned the cultivation of GM crops from their land and the same holds true for the Protestant Church in Germany (Evangelische Kirche in Deutschland, EKD) (e.g. http://www.epv.de/node/3371). Taking this development into account, we suppose that the adoption of Bt-maize is significantly influenced by land ownership rights, favouring farms with more land in individual ownership.

3.4. Importance of organic farms in a region

Organic production is obliged to refrain from any use of genetic engineering and is legally protected against negative side effects of GM crop cultivation by larger distance requirements since 2008. However, the significance of organic farming may also affect other conventional farmers in the neighbourhood in their adoption decision. There are mainly two reasons why a farmer might not adopt Bt-maize if his neighbours are organic farms: 1) higher likelihood to face economic losses due to liability claims because organic produce receives a premium price in Germany and 2) the need to create large maize stands (at least 49 ha for planting 1 ha Bt-maize) to keep the prescribed distance of 300 m to his neighbour(s). Although the larger distance to organic farming was not required from 2005 to 2008, in practice farmer kept larger distances to organic farmers (CONSMÜLLER ET AL. 2008). Therefore we would expect that a higher share of organic farming leads to a lower adaptation rate.

3.5. Number and size of GMO-free zones

An interesting phenomenon of resistance to Bt-maize in Germany and Europe is the establishment of GMO-free zones (Gentechnikfreie Regionen), which has been observed since 2003. GMO-free zones are cooperative arrangements among farmers, land owners or downstream enterprises. This initiative has been supported by the German Association for Environmental Protection and Nature Conservation (BUND) in order to prohibit GM crops on German fields. To become a member of a GMO-free zone, the farmer must contractually refrain from planting GM varieties on his farm. In those regions where significant initiatives for GMO-free-zones are emerging, the social pressure on farms intending to plant Bt-maize might be high. Thus a region with a large share of GMO-free zones may have a negative influence on the adoption of Bt-maize. At the same time, it is possible that the establishment of GMO-free zones is itself driven by the expansion of Bt-maize in a given region. Hence, it is an empirical question whether Bt-maize expansion and the establishment of GMO-free zones reinforce or drive out each other.

3.6. Significance of anti-GMO activists

Many environmental groups (e.g., BUND[2], Greenpeace) are actively involved in the anti-GM movement and support the establishment of GMO-free zones. Since farmers have to report GM field location and size at least three months before seeding to the competent authority, Greenpeace and other groups are able provide detailed information on the location of fields or organise campaigns in order to exert pressure on the GM farmers. In past years, destructions of GM fields have often taken place by members of the German anti-GM movement. A high density of activists in nature groups could therefore be an indicator for GM-opposition in a region and is expected to affect the Bt-maize adoption negatively.

3.7. Time

As for other technologies, adoption of Bt-maize is affected by the time dimension. The benefits and costs of Bt-maize adoption are subject to high uncertainty. On the one hand, the ECB infestation rates may vary from year to year; on the other hand the risk for farmers being held liable for economic damages due to outcrossing is very difficult to estimate. The experiences gained over time may reduce the uncertainty and lead to increasing adoption in the following period.

Summing up, the ECB infestation rates and the maize grown per farm are the two factors generating the benefits of Bt-maize adoption, while the regulatory and social environment impose costs that have partly a fixed cost character. In regions with a high share of rented land, organic agriculture, GM-free regions and many anti-GMO activists we expect the adoption rate to be lower.

4 Econometric Analysis

In order to test the previous hypotheses, we utilize panel datasets at the Federal States and County level. These datasets include regionally aggregated information about GMO adoption and various structural and socioeconomic variables on an annual basis between 2005 and 2007. They cover the early history of commercial Bt-maize cultivation in Germany. Data was obtained from the Federal Statistic Office in Germany, the BVL[3], the statistical service of the churches and from the webpage of the GMO-free zones. The following analysis takes only into account the years in which Bt-maize cropping was legally possible and subject to the first regulatory environment, that is from 2005 until 2007. As outlined above, the legal environment changed significantly in 2008.

Our data allows principally straightforward testing of the previous hypotheses, by using a linear regression model:

$$y_{it} = x_{it}'\beta + \varepsilon_{it}, \quad i = 1, \dots, N, \quad t = 1, \dots, T., \quad (1)$$

where y_{it} is hectares under Bt-maize cultivation for given regions and years, x_{it} is a vector of determinants, β the vector of coefficients that is to be estimated, and ε_{it} a conventional, identically and independently distributed error term. Estimated confidence intervals for β allow to statistically test the above hypotheses. *N* is the number of regions and *T* the number of years. As two modifications of the general model in (1) we estimate a pooled OLS with period effects (equation 2) and a fixed effects model (equation 3) either with or without period effects.

$$y_{it} = \alpha + \lambda_t + x_{it}'\beta + \varepsilon_{it} \qquad (2)$$

[2] Friends of the Earth Germany
[3] Bundesamt für Verbraucherschutz und Lebensmittelsicherheit

$$y_{it} = \alpha_i + \lambda_t + x_{it}'\beta + \varepsilon_{it} \qquad (3)$$

The dependent variable y_{it} indicates the Bt-maize cultivation in May of the respective year. Although farmers are required by law to register the sowing area of Bt-maize early in the year, normally not later than end of January, they often adjust their plans until sowing in end of April or beginning of May. In the last years, usually more than 30% of the initially announced Bt-maize area was withdrawn. This may have different reasons, among others that neighbours adjust their cultivation plans or that GM farmers yield to the pressure of anti-GMO activists. Thus, from a decision making point of view the opportunities and constraints of the current year must be taken into account. For this reason, the explanatory variables x_{it} originate mainly from the same year. Data from the Agriculture Structure Survey are gathered usually in March/April. Data from the GM-free zones are usually summarised in June.

Among the explanatory variables, the ECB infestation rate and the maize area per farm are the most important factors determining the private benefits of Bt-maize cultivation. Unfortunately, systematic and complete annual data on ECB infestation rates is missing. At the Federal States level, the Federal Government of Germany provided information on infestation rates only for the year 2005. The indicator used displays the maize area in ha, where at least 10% of the plants are infested by the ECB. In contrast, the Federal State of Brandenburg provides annual information on the frequency of ECB infestation for the Counties (data source LVLF). This indicator describes the percentage of plants infested by ECB but does not provide exact information on the infested area. In the analysis we make use of both indicators.

Because of the regional aggregation of the data, the maize acreage per farm can only be calculated as a regional average, i.e. the maize area divided by the number of farms. Although not all farms cultivate maize the indicator provides information on possible farm-level profitability to plant Bt-maize. It is important to note that the aggregate data on Bt-maize adoption is the effect of individual decision making. Form an individual point of view, the infested maize area on the farm counts and not the total area in the region. If the total infested area within a region is high, but the individual infested area small, no Bt-maize will be planted, as private benefits do not outweigh the costs. The Bt-maize acreage in a given region may grow if Bt-maize growing farms extend their cultivation or if new farms start growing Bt-maize. Unfortunately, annual data on maize cultivation is only available for the Federal States level. For the County level in the State of Brandenburg information on maize plantation exists only for 2007.

As it was argued, the Bt-maize cultivation may be negatively affected by the significance of organic farming, amount of rented land, GMO-free zones and the anti-GM movement. The significance of organic farming is indicated by the share of organic farming in the Utilisable Agricultural Area (UAA). For the ownership in land, we used the share of owned land in the UAA, and for the GM-free regions the share of declared GM-free land in total UAA. Finally as an indicator for the strength of the anti-GM movement we used share of BUND members in the total population. The data availability differs between the Federal States and the County level. The share of rented land and the number of environmental activists are not available for Brandenburg Counties. We therefore estimate different models for the two aggregation levels.

There are two methodological problems in estimating consistent parameters in (1). First, as [Bt-maize area in the Federal States] shows, the various States differ by orders of magnitude in their cultivation levels of Bt-maize.[4] One likely reason is the principal differences in farm structures between East and West Germany. Furthermore, there may be important latent

[4] There are five observations with zero Bt-maize in the dataset. While this indicates slight censoring of the dependent variable, we ignore this problem in the following.

variables having an impact on y_{it}, such as climatic and soil conditions, or unobserved abilities and preferences of farmers and consumers. Second, several variables in x_{it} may not be independent of the Bt-maize cultivation decisions of farmers. Notably, this could be the case for the maize area planted per farm and for the establishment of GMO-free zones which were probably be set up in response to impending or actual Bt-maize cultivation in a given region. Both problems will make ε_{it} no longer independently distributed, so that estimates of β are inconsistent.

We address the first of these concerns by including regional fixed effects in the regression model. As a consequence, β will capture only the effect of relative changes in x_{it} on y_{it}, independent of the absolute level of Bt-maize cultivation. To the extent that they are time invariant, also the effects of all latent determinants of y_{it} will in this way be eliminated. In order to filter out the effects of changes in the overall environment that are identical for all farms, such as annual price variation, we also include year dummies in the model.

The second concern is addressed by estimating an instrumental variable regression (2SLS) for the Federal States level. The idea is to first estimate for maize area per farm and GMO-free zones which endogenise these variables. It uses predictions from a first stage instrumental variable equation to estimate the equations of the system in the second stage. The results of this model are presented in addition to a more conventional single equation pooled OLS model. As data on maize cultivation and environmental activists is missing for Brandenburg Counties, we present single equation results for this model only.

5 Results

Estimation results for German Federal States are displayed in Table 1. Model A presents the results from a pooled ordinary least squares (OLS) model with time effects, whereas model B shows an instrumental variable (IV) model where the maize area per farm is instrumented with the average farm size per region. This model accounts for the possible endogeneity of the maize area per farm. Model C presents a fixed-effects model that also takes into account possible regional and time effects.

Table 1: Regression estimates for Bt-maize cultivation in the German Federal States

Explanatory variables	***Pooled OLS period effects (A)***			***Pooled IV period effects (B)***			***Fixed Effects and period effects (C)***			***Mean values***
Bt-maize[a(]	*Coefficient*		p-*value*	*Coefficient*		p-*value*	*Coefficient*		p-*value*	
ECB infested area (ha in 2005)	-0.002		0.327	-0.001		0.564	-	-	-	28707
Maize area per farm (ha)	25.06	***	0.001	18.10	**	0.018	184.61	***	0.003	7.67
Land in cultivators' ownership (% of UAA)	-2.098		0.603	-2.623		0.524	54.59		0.268	31.67
Organic farming area (% of UAA)	13.33		0.464	19.20		0.305	54.59		0.561	5.36
GMO-free zones (% of UAA)	2.91		0.790	0.030		0.998	45.39		0.245	5.05
BUND members (% of population)	347.06		0.233	256.41		0.387	-5055.3	*	0.075	0.36
Year 2006 (dummy)	40.16		0.613	42.55		0.599	-94.45		0.205	0.33
Year 2007 (dummy)	149.30	*	0.070	158.15	*	0.060	-116.36		0.260	0.33
Constant	-234.78		0.182	-178.21		0.319	-1716.7		0.365	
Adjusted R^2	0.391			0.369			0.811			

Notes: [a] Dependent variable is Bt-maize per region in the same year (ha). Model (B) uses farm size in ha as an instrument for maize cultivation. ** (***): significant at 5% (1%) level. N=39 for all regressions.

Source: Authors' calculations.

The results show that the main factor affecting the plantation of Bt-maize is the average maize area grown on the farm. This result is robust over the whole range of models calculated. Surprisingly, the ECB infested area does not have a significant impact. There may be several reasons for this: First, the information of the ECB infestation originates from 2005 and is not updated for 2006 and 2007. Thus, the dynamics of the infestation rates could not be taken into account. Second, in Federal States where the infested area is large in total, but small per farm, farmers are unlikely to adopt Bt-maize because of the fixed regulatory (and social) costs. This seems to be the case in particular for Bavaria and Baden-Württemberg where in the ECB infested area is estimated with 180,000 and 60,000 ha, but the adoption of Bt-maize is only 5.8 and 7.2 ha (2007) respectively. The farm size and the maize cultivation per farm are among the smallest in Germany. Land ownership, organic farming, GMO-free zones and BUND members have no effect in models A and B. In model C, the increase over time in the number BUND members has a significant negative impact on the adoption of Bt-maize. This suggests that the anti-GM groups have a negative impact on Bt-maize adoption.

The results for Brandenburg Counties are shown in Table 2. Certain variables were not available, such as maize per farm (which was only available for 2007), land ownership and the members of BUND. However, the information on the ECB infestation goes more into the details as they provide yearly indicators for the frequency of infestation. The main interest here is whether infestation with ECB affects Bt-maize adoption in the following year. The pooled OLS model (A) as well as the fixed effects model (B) demonstrates a positive effect, as expected, which is significantly different from zero at least at the 1 and 10 percent level respectively. However, the effect vanishes once year dummies are included in the fixed effects model. It follows from a closer inspection of the data (not shown in the table) that relative changes of adoption rates in Brandenburg Counties follow previous year infestation rates with ECB rather well. Even so, as both infestation and adoption rates are uniformly low in the first year of our sample, the model cannot statistically discriminate between a general macro effect and an effect of ECB infestation if year dummies are included. Interestingly, the increasing size of GMO-free zones has a statistically negative effect in model B and C on the Bt-maize adoption rates in Brandenburg.

Table 2: Regression estimates for Bt-maize area in Brandenburg Counties

Explanatory variables	***Pooled OLS with period effects (A)***			***Fixed Effects (B)***			***Fixed effects with period effects (C)***			***Mean values***
	Coefficient		p-*value*	*Coefficient*		p-*value*	*Coefficient*		p-*value*	
ECB Infestation (frequency)	6.072	***	0.000	3.505	*	0.074	2.378		0.247	20.48
Organic farming area (% of UAA)	-1.019		0.467	11.432		0.627	5.341		0.822	10.88
GMO-free zones (% of UAA)	-3.228		0.924	-8.664	*	0.052	-9.155	**	0.043	0.98
Year 2006	37.600			-			58.452	*	0.097	0.33
Year 2007	24.373			-			39.726		0.279	0.33
Const.	-55.214			-112.21		0.664	-55.066		0.832	
Adjusted R^2	0.416			0.529			0.340			

Notes: Dependent variable is Bt-maize area in subsequent year (ha). Model (B) includes 13 county dummies, model (C) 13 county and two year dummies. *, **, ***: significant at 10, 5 and 1% level. N=42 for all models.

Source: Authors' calculations.

6 Conclusions

Our analysis shows that the regional differences in Bt-maize adoption are affected by agricultural structures and the activities of the anti-GMO movement. The regulatory environment in Germany introduces additional fixed and variable cost to adopters of Bt-maize. Although Bt-maize is a scale neutral technology controlling for damages caused by the

European Corn Borer (ECB) the additional fixed and variable costs transform the technology into a scale dependent one. As the empirical analysis of panel data at the Federal States level show, the maize area grown per farm is the single most important factor explaining regional and temporal variance in Bt-maize adoption. At the Federal States level no relationship could be identified between the ECB infestation rates and the Bt-maize adoption. One main reason seems to be that farms with little maize acreage resign completely from Bt-maize adoption even if they face high ECB infestation rates. In contrast, at the Brandenburg County level the ECB infestation frequency turns out to be an important factor explaining the adoption of Bt-maize. Brandenburg, however, is characterised by large-scale maize farming, where the size of maize strands are unlikely to constrain Bt-maize adoption.

Surprisingly, other factors such as land ownership and organic agriculture do not explain the regional and temporal variation of Bt-maize adoption on the Federal State level. However, there is some indication that anti-GMO activists and GMO-free zones have a negative impact on Bt-maize adoption. Whereas at the level of the Brandenburg Counties the increasing size of GMO-free zones constrains the adoption of Bt-maize, this could not be confirmed for the level of the Federal States.

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