Exploring the constraints to further expansion of GM maize production in Portugal

Article

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Exploring the Constraints to Further Expansion of GM Maize Production in Portugal

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After 10 years of GM maize cultivation in Portugal, the area produced remains modest, at 6.3% of total maize production in 2015. This fact suggests that significant constraints to further expansion continue to exist. Through a survey of the structural and attitudinal characteristics of GM and conventional maize producers, this article explores constraints to adoption of GM crops in Portugal. The survey revealed a complex mix of barriers based around structural and attitudinal factors. For example, GM adopters managed larger farms than conventional, with double the area of maize grown. GM maize growers felt more constrained (in terms of factors depressing yields) by pests, especially corn borers and weeds than their non-GM counterparts. A number of non-structural barriers to GM uptake were also identified, such as perceived public opposition to GM cultivation and increased management burden associated with coexistence measures, through the requirement to make decisions in conjunction with neighbors.

Key words: barriers to uptake, coexistence measures, GM maize.

Introduction

In spite of a 31% decline in the area produced since 2004, at 147,000 ha, maize remains the third-most extensively grown crop in Portugal after olives and grapes (Anpromis, 2014). Maize is particularly important in arable rotations on smaller farms, where it can make up one-third of the cultivated area (Anpromis, 2011). Maize is grown primarily for livestock feed, as the crop is better suited to the hot, dry summers than forage grasses, although irrigation is usually required with the onset of the spring growth phase. Maize is cultivated in all regions, but some two thirds of the total area is in the North and Central regions of the country; however, production is now expanding in the South because the new Alqueva dam has increased irrigation potential. Maize is one of the more commercialized crops in Portugal, with a significant proportion of the crop being sold off-farm; therefore, the maize supply chain, both in terms of inputs and outputs, is more highly organized than many other crops.

Insect-resistant (IR) Bt maize was introduced in Portugal in 1999. Then, following a 5-year European Union moratorium, it was re-introduced for cultivation in 2005, the year when national coexistence rules were first published (Decree Law No. 160 of 21 September 2005). Bt maize was developed as a means of controlling corn-boring insect pests, primarily *Ostrinia nubilalis* (i.e., the European corn borer [ECB]) and *Sesamia nonagrioides* (i.e., Mediterranean corn borer). These pests can be a major cause of yield losses in some areas of Portugal, especially in the Alentejo and Lisboa e Vale do Tejo regions, where annual infestation rates are highest (Brookes, 2007). Skevas, Wesseler, and Fevereiro (2009) confirmed that the primary driver of uptake of GM maize in Portugal has been control of corn borers as a means to achieving income gains through yield protection and input cost reduction. This driver is also prevalent in other countries (for an international review, see Qaim, 2009, and for Spain see Gómez-Barbero, Berbel, & Rodríguez-Cerezo, 2008). Bt maize has proven beneficial in controlling corn borers in Portugal; Brookes (2007) estimated gross margin improvements over conventional maize of €112/ha on average in 2006, while Wesseler, Scatasta, and Nillesen (2007) reported total incremental benefits of €194/ha. Some other drivers of uptake have also been identified in Portugal, such as concerns to lessen risks to the environment and worker health through reduced use of pesticide (Skevas et al., 2009). Studies in other countries—for example, Marra and Piggott (2006) and Ervin et al. (2010) —have identified other drivers (including perceived non-monetary benefits such as simplification of farming operations, for example through less pest management) that result in lower labor requirements. The role of non-monetary benefits in driving GM maize uptake in Portugal is less obvious, but this question will be revisited in this article.

In spite of the drivers identified above, the rate of uptake of Bt maize in Portugal has been slow and the

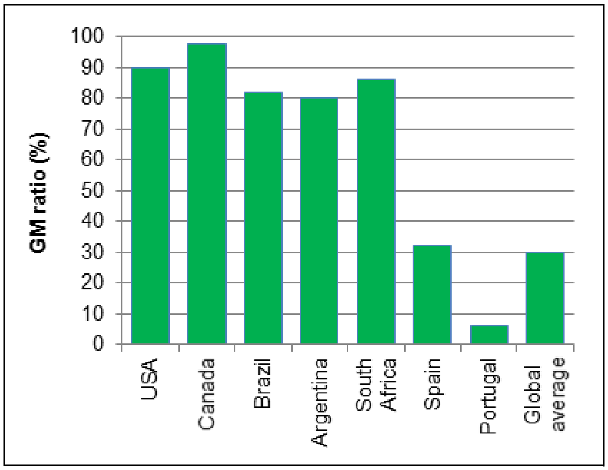

Figure 1. GM maize ratio (proportion of total maize production) for Portugal and a selection of other producer countries.

Source: James (2014).

area of production seems, for the moment, to have stabilized at just 5-6% of the national maize area. This GM maize ratio is very low in comparison with the ratios observed in other industrialized countries, such as the United States, Canada, Argentina, South Africa, and Brazil, which have ratios in excess of 80% (see Figure 1). In neighboring Spain, one of the few other EU countries to grow GM maize, the ratio is close to the global average of 30% (James, 2014).

It is obvious from this low GM-to-non GM ratio that very significant constraints must exist to further expansion of the GM crop area in Portugal. But what are these constraining factors and how would these need to change to allow for further expansion of GM maize production? Past studies have identified a number of constraints to GM uptake in other countries that may have relevance in this case. These constraints include the structural characteristics of the farm population, such as farm size (Jones & Tranter, 2014); the economics of GM production (Bullock & Nitsi, 2001; Phillips, 2003; Qaim, 2009); increase in management complexity, including the burden of coexistence measures (Areal, Riesgo, Gómez-Barbero, & Rodríguez-Cerezo, 2012; Beckmann, Soregaroli, & Wesseler, 2006; Quedas & Carvalho, 2012); the cost of GM seed (Jones & Tranter, 2014; Skevas et al., 2009); the availability of markets for GM produce; and farmer attitudes to these technologies (Areal et al., 2012; Jones & Tranter, 2014; Keelan, Thorne, Flanagan, Newman, & Mullins, 2009).

An obvious potential constraint to GM uptake in the context of agriculture in Portugal is farm size. Jones and Tranter (2014) have shown an inverse relationship

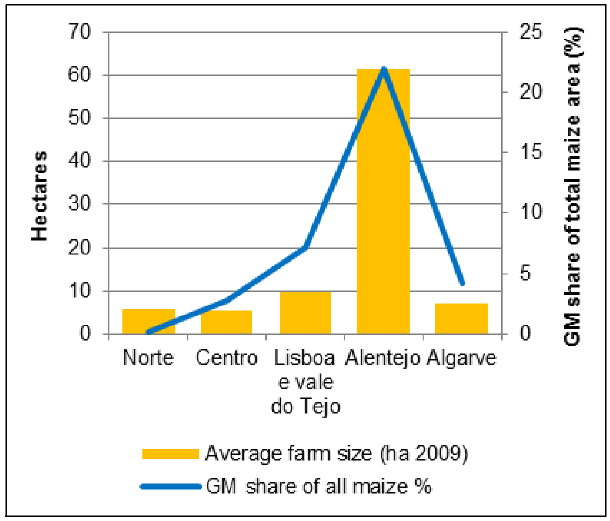

Figure 2. The ratio of GM maize (to all maize production) compared with average farm size in each region of Portugal, 2013.

Source: Anpromis (2014) and authors' own calculations.

between farm size and rates of uptake of (or intention to take up) GM technologies. Other studies—for example, Soregaroli and Wesseler (2005) and Skevas et al. (2009)—have shown that a constraint occurs when farm size interacts with some coexistence requirements, such as minimum separation distances. Large minimum separation distances, as they exist in Portugal, discriminate against smaller farmers by eroding the proportion of the farm that can be planted with GM to the point that potential economic benefits from using the technology are offset by additional (including coexistence) costs. In Portugal, average farm size is just 12 ha, with the majority of farms possessing utilizable agricultural areas (UAA) of 5 ha or less (Statistics Portugal, 2011). The dominance of very small farms in Portugal, therefore, represents a significant structural barrier to further growth in GM maize uptake. Consistent with this observation, Figure 2 shows there is an obvious association between average farm size and the GM maize ratio in Portugal, with the GM ratio rising to over 20% in the Alentejo region, where the average farm size rises to some 60 ha. However, even in the Alentejo region the GM ratio is well below the global average, and this fact strongly suggests that, while farm size, or rather the interaction of farm size with some coexistence measures, must be a major constraint, it would be wrong to say that this factor is the only constraint in operation and that other constraints must also exist, especially among farmers with larger farms.

Table 1. Farm and farmer characteristics—Comparison of participating GM and non-GM maize growers.

Characteristics	GM maize growers	Conventional maize growers	Significance of differences
Years in farming	27.2	24.3	t=0.83; P=0.4112
Age in years	49.4	44.8	t=1.47; P=0.1477
UAA of farm (ha)	384.6	135.3	t=1.31; P=0.2012
Percent of UAA that is rented	8.6	22.5	t=0.14; P=0.8906
Maize area in ha (% of UAA)	83.6 (21.7)	46.6 (34.4)	t=2.27; P=0.0286
Numbers of other farms bordering the surveyed farm	24.2	21.1	t=0.37; P=0.7133
Number of farm staff	2.7	2.9	t=-0.52; P=0.6035
Obtained a university degree (%)	34.6	30.8	X^2=0.2657; P=0.9919

Before there can be any significant expansion of the GM maize area in Portugal, the constraints to further uptake of the crop must be identified so that remedial actions to remove these constraints, perhaps in the form of policy interventions, can be developed. The study reported here used a survey of GM and conventional maize producers, and makes comparisons between these two groups on key dimensions as a means to identifying and understanding these constraints, with a particular focus on farm structural issues and farmer attitudes, including the influence of coexistence requirements on farmer attitudes.

Method

Data was collected from GM and non-GM maize growers in Portugal by means of an in-depth survey questionnaire. This questionnaire was designed in conjunction with six national partners in the EU PRICE (PRactical Implementation of Coexistence in Europe) project (Czech Republic, Germany, Portugal, Romania, Spain, and the United Kingdom) by means of an iterative review process. The survey was applied simultaneously in all study countries and to all regions of Portugal, excluding the Azores and Madeira. For confidentiality reasons, the Ministry of Agriculture for Portugal could not supply a contact list of registered GM growers, so contact details were obtained from three alternative sources—a list of farmers attending the National Association of Maize and Sorghum Producers' (Anpromis) 2012 National Maize Congress, membership lists for the farm co-operative movement in Portugal, and seed industry customer lists.

Data was collected by means of face-to-face interview over the winter period (a quiet period for farm operations) of 2012/13. Interviews were conducted with 27 conventional maize growers and 29 growers of GM maize (11.6% of the 250 registered GM maize growers in 2011). Stratification of the sample was undertaken by geographical region by ensuring that the number of GM maize farmers interviewed in each region was broadly proportional to the number of registered GM farmers in each region. Two factors acted to constrain the numbers of farmers willing to participate in the survey—survey fatigue (i.e., farmers complained of being obliged to take part in numerous official and industry-run surveys each year) and the length and necessary detail of the current survey questionnaire. All results refer to the harvest year 2012.

Results

Sample Characterstics

In terms of farmer characteristics, relatively few differences were observed between participating GM and conventional maize growers (see Table 1). While GM famers appear to be slightly older, more experienced, and slightly better educated than their non-GM counterparts, these differences were not found to be statistically significant, although with larger sample sizes some of the differences observed might have become significant.

In terms of farm characteristics, there is an obvious difference in farm size between GM and non-GM farms, i.e., average GM farm size is two and a half times that of non-GM farms. This difference is not statistically significant, but this is perhaps due to the relatively small sample size and extreme heterogeneity in the sub-samples. There is, however, a significant difference in the size of the maize area grown, i.e., the maize area on GM farms is double that on non-GM farms. Other (non-significant) differences are that non-GM farmers tend to have a much larger proportion of rented land and the maize area takes up a larger share of the UAA.

The size (UAA) difference between GM and non-GM farms reinforces the observed inverse relationship between average farm size and rate of GM uptake seen in official statistics. The fact that farms in both sub-sam-

Table 2. Perceived constraining factors[a] affecting respondents' ability to get the best crop yields.

	GM maize growers	Conventional maize growers	Significance of differences
Soil quality	4.07	2.44	t=4.50; P=0.0001
Water availability	2.12	2.20	t=0.88; P=0.3554
Weeds	3.28	4.04	t=-1.83; P=0.0729
Pests	3.10	4.22	t=-2.50; P=0.0155
Seed quality	3.62	4.85	t=-2.09; P=0.0414
Topographic factors	1.35	2.11	t=0.89; P=0.3882
Climate	3.89	3.33	t=1.05; P=0.2978

[a] *Expressed as mean rank scores, where 1=high relevance/importance, 7=low relevance/importance*

ples are, on average, much larger than the target population, might suggest some self-selection bias in the sample. However, this effect is more likely due to the fact that sampling is skewed towards the Alentejo region (because the majority of GM adopters are present here), where farm sizes are much larger on average than in other regions. However, the fact that these data are based on larger-than-average farmers helps to eliminate, to a great extent, the confounding effect that farm size might have on an exploration of the role of other barriers to GM uptake.

Environmental Factors Constraining GM Maize Adoption

It is probable that farmers' decisions on GM crop uptake may be influenced by the agronomic challenges that they face, i.e., the environmental factors that constrain maize yields. It is logical to expect, for example, that farmers facing regular and heavy insect pest pressure would be more inclined to look to IR maize as a possible solution to this constraint than farmers who do not face such pressure. Therefore, farmers in the survey were asked to rank the extent to which achievement of good maize yields is constrained by a number of 'environmental' challenges. The survey used a 7-point ranking scale, where lower ranking scores imply greater perceived challenge (see Table 2). Both types of growers perceived the biggest agronomic challenges to be water availability (hence, the reliance on irrigation) and topographical factors. As might be expected, Table 2 reveals a statistically significant difference between GM and non-GM producers in their evaluation of pest risk, with GM producers perceiving this as a greater risk. GM farmers also reported a greater risk from weeds (borderline statistical significance). While seed quality was not recognized as a major concern by either group, it was perceived as more of a challenge to GM producers. In this case, GM growers are perhaps not so much concerned with seed physiology (for example, in terms of germination rates) but rather in terms of genetics (i.e., the process of choosing varieties to deal with environmental stressors is more time-consuming).

Table 3. Respondents' ranking[a] of the significance of crop losses from corn borers if not controlled properly.

Nature of problem	GM maize growers	Conventional maize growers	Significance of difference
European and Mediterranean corn borers	7.69	6.33	t=2.50; P=0.0155

[a] *Where 1=not significant and 10=most significant*

To further explore the perceived challenge from pests, farmers were asked to rank the extent of the challenge faced specifically by corn borers, i.e., they were asked to estimate the significance of the yield losses they would experience if corn borers were not effectively controlled. Again, as would be expected, GM growers anticipated a significantly higher risk of losses from this pest than their non-GM counterparts (see Table 3).

Socio-economic Barriers to GM Maize Adoption

The analysis presented above has identified a number of structural (including environmental) factors that seem to have an influence on the likelihood of adoption of GM maize in Portugal. However, there may be other types of barrier not so far identified, particularly arising out of perceived social and economic (including farm management) concerns. To explore this possibility, non-GM maize farmers were asked to rank the importance of a number of potential economic and social constraints that might have influenced their decision not to take up GM maize. Table 4 shows their level of agreement with statements expressing different possible reasons for not growing GM maize. As Table 4 shows, non-GM farmers identified relatively few such reasons for non-adoption. The most commonly cited reason (by some 60%) was

Table 4. The proportion (%) of conventional maize farmers identifying the following reasons for not growing GM maize.

	Percent of non-GM producers
I do not think there would be an increase in yields.	7.4
I do not think there would be an increase in economic returns.	7.4
I do not believe in these new kinds of crops.	0
I prefer not to change my type of crop.	25.9
I think GM maize would be difficult to sell.	3.7
I have more faith in the use of insecticides to combat the corn borer.	3.7
A majority in society is opposed to it.	59.2
It is associated with complicated management (e.g., coexistence rules).	53.8
I grow maize under specific standards that forbid GM (i.e., organic).	7.4
It would cause conflict with my neighbors.	7.4
The seed is too expensive and not generally available.	7.4

the perception that the majority in Portuguese society were opposed to the production of GM maize. The next most commonly cited constraint (by almost 54%) was the perception that adoption of GM maize would complicate, and therefore increase, their management burden. This may either relate to the level of general agronomic management, or to perceptions of the burden involved in compliance with coexistence rules. The third constraint commonly identified by non-GM farmers appears to be rooted in inertia—while some farmers may accept that GM maize may be beneficial in protecting crop yields from pests, and while they may have no philosophical or ethical objection to the introduction of these new technologies, they simply do not want the bother of making these changes.

Attitudinal Barriers to GM Adoption

The fact that a majority of non-GM farmers cited perceived public opposition to GM maize as one of their reasons for non-adoption raises the possibility of the existence of additional attitudinal barriers to adoption. In an attempt to try to understand the role of farmer attitudes in decisions to adopt or reject adoption of GM maize, respondents were shown a list of 15 attitudinal statements related to agriculture, GM crops, food, and the environment and were asked to indicate their level of agreement, on a 5-point Likert scale, with each. Table 5 shows the percentage of farmers, of each type, who 'agreed' or 'strongly agreed' with each statement.

What is most striking in these results is the level of similarity in the responses of GM and non-GM maize growers, suggesting that attitudes toward food (and, by implication, feed), health, and environmental risks, as well as attitudes toward GM technologies, are broadly similar. Neither group believes, to any great extent, that GM technologies pose a significant or unmanageable risk to either the environment or human health. Both groups are supportive of the use of GM technologies, if farmers wish to use them, and both strongly believe that EU agriculture will be disadvantaged if the use of such crops is not authorized. There was, in fact, only one statistically significant difference between the two groups of farmers: GM maize growers had much more confidence in the trustworthiness of food labels than did their conventional counterparts. This suggests that if there is any skepticism towards GM by non-adopters, it is connected to the issue of the marketing of GM and non-GM products. This skepticism may stem from the practice of feed maize marketers in Portugal not guaranteeing GM-free supplies and marketing all maize as containing GMOs.

Coexistence Measures as Barriers to GM Adoption

As indicated in Table 4, slightly more than half of all non-GM producers indicated that the perception of likely increases in management burden was a barrier to their adoption of GM maize production, where this management burden was explicitly linked to compliance with coexistence measures. GM producers are obligated to comply with a raft of compliance measures in Portugal (for a full description of these measures, see Chiarabolli, 2011), including the requirements to:

- Either use spatial isolation of 200m from conventional maize or 24-row buffer zone
- Either use spatial isolation of 300m from organic maize or 24-row buffer zone plus 50m isolation distance
- Alternatively, replace spatial isolation with temporal isolation (adjustment of planting dates)
- Refuges of conventional maize (20% of GM area)

Table 5. Proportion (%) of respondents in agreement with a series of attitudinal statements related to GM crops, food, and agriculture.

Statements	GM farmers	Non-GM farmers	Statistical significance of differences
If the majority of EU consumers are in favor of GM crops they should be approved for use.	81.5	88.5	X^2=0.77; P=0.3802
If farmers think that a GM crop is useful to them they should be allowed to grow it.	82.8	100.0	X^2=2.68; P=0.1017
Food labels can be trusted.	61.5	30.8	X^2=6.36; P=0.0116
I think additives in food are not harmful to my health.	26.9	36.0	X^2=0.57; P=0.4466
The health risks surrounding GM crops can be managed by the Government.	56.0	50.0	X^2=0.00; P=0.9924
The environmental risks surrounding GM crops can be managed by the Government.	69.2	57.7	X^2=0.25; P=0.6206
When humans interfere with nature, disastrous consequences result.	17.9	16.0	X^2=0.06; P=0.8049
Among the risks we face in our lives, those impacting food safety are very important.	89.6	96.1	X^2=0.15; P=0.7001
Pesticides and fertilizers are dangerous to the environment.	82.2	88.4	X^2=0.33; P=0.5663
We can eradicate the diseases and pests that attack crops by using GM crops.	60.7	56.5	X^2=0.62; P=0.4323
GM crops are against nature.	0	0	N.A.
Harmful environmental effects of GM foods are likely to appear in the future.	7.4	12.5	X^2=0.31; P=0.5798
Harmful human health effects of GM foods are likely to appear in the future.	7.4	8.3	X^2=0.01; P=0.9409
GM crops are the future of agriculture.	96.4	92.2	X^2=0.31; P=0.5805
Rejecting GM crops will make EU farmers uncompetitive in the world market.	96.5	100.0	X^2=0.43; P=0.5109

- Keep records of the production process

Or

- Negotiate a production zone containing neighboring GM and non-GM farmers, whose maize will all be labelled as GM

While non-GM farmers may not have had direct experience with some of these measures, they will very likely have developed a perception of the burden associated with some of the measures through interaction with neighboring GM growers, amongst others. To explore the nature of this perception, non-GM producers were asked to rank the degree of burden associated with a selection of coexistence measures using a 5-point ranking scale. These measures were based on an assessment of those aspects of the full set of coexistence measures relevant to Portugal that they would have personally experienced as neighbors of GM producers, plus a number of additional measures not currently operating in Portugal, but deployed in some other EU countries.

As Table 6 shows, based on non-GM farmers' own experience of interaction with GM neighbors, the most burdensome measures were perceived to be those that involve negotiation with neighboring farmers over either sowing dates to ensure temporal isolation, or cultivar choices to ensure differences of at least 2 FAO (Food and Agriculture Organization of the United Nations) cultivar classes in contiguous plantings of maize. The extent of this burden must be due in part to the sheer number of neighboring farmers involved, i.e., in excess of 20 on average (see Table 1).

In terms of the hypothetical measures (i.e., measures that non-GM farmers have yet to personally experience), the idea of having to establish isolation distances was viewed as less burdensome than securing permission to plant the GM crop. While this relatively low burden ranking for the isolation distance may be attributable to the smaller distance involved (i.e., 75m as opposed to the 200m distance currently operating in Portugal), it is also possible that farmers did not view this as particularly burdensome because of the availability of an alternative measure (i.e., establishing smaller [24 row] buffer zones). It is interesting to note that GM farmers also follow this pattern of ranking the burden of third-party negotiation higher than they do the establishment of production zones. Non-GM producers appear to rank the establishment of production zones as less burdensome even than GM farmers. This is unexpected for two reasons: 1) non-GM farmers do not get any personal advantage from doing this, i.e., it is only beneficial to farmers that intend to grow GM-maize; and 2) with

Table 6. GM and non-GM producers' rank[a] of the perceived burden of a number of different coexistence measures.

	Rank of burden	
	Non-GM farmers	GM farmers
Coexistence measures current in Portugal		
Provide written communication with neighbor of intention to grow GM	2.04	4.81
Verification of isolation distances	1.79	N.A.
Negotiation with other farmers on sowing dates to achieve interval of at least 20 days for cultivars of same FAO class	3.63	4.00
Choosing cultivars with neighbors to obtain differences of at least 2 FAO classes on crops sown at the same time	4.33	4.33
Negotiation with other farmers to establish production zone	2.84	3.04
Establish an isolation distance of 200m	N.A.	3.17
Coexistence measures not current in Portugal		
Establish 75m isolation distances	2.72	
Secure government authorization to grow GM maize	4.40	
Secure authorization of neighbors to grow GM maize	4.00	

[a] *Where 1=easy to implement; 5=very high burden*

much smaller farm sizes, isolation measures or buffer zones are much less feasible.

Taken together, these results suggest that non-GM producers perceive that any action dependent on negotiation with third parties for success will likely be problematic. Those actions that lie within the sole control of the farmer themselves are not seen as so problematic, even when these may require significant inputs of time or changes to management practices.

Discussion and Conclusions

This article has explored the nature of the barriers to greater uptake of GM maize in Portugal by means of a survey of GM and non-GM farmers. While more than 10% of all GM maize growers were surveyed, the total sample is relatively small and so it is with some caution that generalizations from the survey results are undertaken. However, a number of statistically significant differences between GM and non-GM farmers have been found and these can, with some confidence, be seen as robust. Due to the regional stratification employed, average farm sizes for both GM and non-GM growers are considerably larger in the survey sample than the average in Portugal. However, this fact has allowed us to look beyond the interaction between farm size and separation distances that normally form the focus of studies of barriers to GM adoption, especially in countries such as Portugal that have a predominance of small farms. The picture that has emerged is complex, with multi-dimensional barriers being revealed; some of these are rooted in farm structural and environmental issues, some based on perceived changes to management complexity, and some derived from farmer and societal attitudes.

A Framework for Understanding Barriers to, and Drivers of, GM Uptake

A more holistic understanding of the mix of barriers to GM uptake identified in the study reported here, as well as others reported in the literature, can perhaps best be achieved through use of models of human decision making derived from the disciplines of psychology and sociology. One such model is the theory of planned behavior (TPB; Azjen, 1985, 1991; Azjen & Fishbein, 1980), which states that behavioral choices are determined by states in three different dimensions—personal attitudes towards the behavior, or the outcome of the behavior (i.e., whether these outcomes are highly valued); the attitudes of respected peers towards the behavior (or the outcome); and perceptions of the extent to which the execution of the behavior (or the achievement of the outcome) can be controlled. These TPB dimensions are known as: outcome attitudes, social referents, and perceived behavioral control, respectively. It is interesting to note that all of the barriers to uptake of GM technologies identified in this (and other studies) fit neatly into these three dimensions.

The two main, non-structural reasons cited by conventional maize growers for non-adoption of GM maize (i.e., public opposition to GM technologies and increased burden of management, particularly in relation to coexistence requirements) fit into the social referents and perceived behavioral control dimensions, respectively. The third dimension of the TPB behavioral model (outcome attitudes) captures both structural (e.g., farm size) and non-structural effects (e.g., attitudes towards the GM technologies), both of which can lead to barriers or drivers of GM uptake.

Outcome Attitudes

Attitudes toward GM maize growing can be influenced by background attitudes to GM technologies more generally. These attitudes will have been developed in the course of the farmers' own learning and knowledge acquisition processes and are influenced by data transfer from a number of information sources, such as farm advisers, the scientific community, the media, and neighboring farmers. The study reported here found that conventional maize producers share many of the same positive background attitudes toward GM technologies as GM adopters. For example, both groups believe that there is nothing intrinsically wrong with GM technology and that it can, under the right circumstances, provide economic benefits, and also that it poses no significant (or unmanageable) risk to human health or the environment. This positive background attitude toward the technology acts as a driver of uptake.

Attitudes can also be influenced by structural considerations. For example, if farmers do not perceive that they experience significant pressure from corn borers, they will have a negative attitude towards the outcome of adopting Bt maize, because they will perceive that uptake will lead only to additional costs and no yield benefit. The survey found that the level of pressure (or at least the perception of it) from corn borers is lower among non-adopters than those who have adopted GM maize. Thus, the structural state can act as a barrier to adoption of GM maize through the creation of negative attitudes toward the outcome of adoption.

Social Referents

The survey reported here found that many conventional maize growers are allowing their decisions on adoption of GM maize to be influenced by the negative views that citizens as a whole hold about this technology. In terms of the TPB model, this translates into a perception of how ‘important’ others—in this case, citizens—would feel about the farmer growing the GM crop. It is interesting to speculate why the opinions of citizens should be so influential when the behavioral model suggests that the most influential peer groups are usually close friends or family, or others with respected knowledge, or with influence over business success, such as customers. This finding might be explicable if growers perceived that adverse public opinion would lead to loss of markets but, in this case, the survey results show that growers do not expect that they would have difficulties in marketing the GM product. Is farmer rejection of GM therefore, in part, a public relations exercise?

Perceived Behavioral Control

It has been observed in a number of studies that GM crops with input-side traits provided the advantage of simplified management. For example, Bullock and Nitsi (2001); Fernández-Cornejo, Hendricks, and Mishra (2005); Marra and Piggott (2006); Carpenter and Gianessi (1999); and Ervin et al. (2010) all observed that IR and herbicide-tolerant crops require less pest management (i.e., require less monitoring of pest levels and less spraying/fewer passes) with insecticide. In terms of the TPB model, easier management leads to more favorable perceived behavioral control. It has been suggested that this outcome might appeal to smaller farmers for other, more practical reasons, as it would allow for the release of labor resources for use elsewhere, such as on-farm, or off-farm income-generating activities. However, in Portugal, among this sample of larger-scale non-adopters of GM maize, some aspects of coexistence, particularly the requirement to interact with, and secure the cooperation of, neighboring farmers adds complexity to the point of offsetting the potential benefits of simpler pest management. This observation confirms the findings of Skevas et al. (2009), who noted that 67% of GM maize producers reported difficulties informing neighbors of planting intentions, with the level of difficulty increasing with the number of neighbors involved. Contributing to this perception of increased complexity is the loss of direct managerial control over decisions, i.e., the farmer is dependent on the decisions of others in order to undertake behaviors. This observed unfavorable outcome (i.e., reduced perceived behavioral control) would obviously act as a barrier to uptake of GM maize.

Implications for Policy

From a policy perspective, some of the constraints identified in the study reported here would appear to be more tractable than others. Where negative farmer attitudes toward GM uptake are based on real-world factors that cannot be easily changed, then it would be difficult to affect change in those attitudes. For example, if farmers do not have the agronomic problem that the technology targets, then they will not anticipate economic benefits from using it. Demand for the technology will therefore be based on true need, and if this is saturated then the prospects for expansion of the planted area are poor and expansion would only occur through the availability of alternative traits, such as herbicide tolerance or drought resistance, or a stacked combination of these. Demand for such alternative traits among maize growers in Portugal has been confirmed by Skevas et al. (2009) and is evident in a growing pest problem affecting maize production caused by the soil fungus *Cephalosporium maydis*, which has led many farmers to seek out non-GM *Cephalosporium*-tolerant varieties (Portuguese Ministry of Agriculture, personal communication, 2014). The advent of this new pest may also have contributed to the relatively slow uptake of Bt maize in Portugal. However, the much higher GM maize ratios found in other countries suggest that, to some extent at least, the lower assessment of pest risk amongst non-adopters must be due to differences in perception of challenge, rather than real challenge. For example, two farmers may face the same level of corn borer challenge, but one might place a lower valuation on the economic losses likely to result from infestation than the other. In these cases, farmer demand for Bt maize might be increased through better education.

One area where policymakers can obviously reduce barriers to GM maize uptake is through the removal of the constraints that exist within the package of coexistence measures currently in operation. However, even here, there are constraints to what can be achieved. Policymakers cannot just drop specific coexistence measures—even when these have been shown to be burdensome—if these are essential to maintaining successful coexistence. It is beyond the scope of this article to make judgements about the utility of specific coexistence measures, but it would be reasonable and beneficial to at least suggest areas where policymakers might usefully address their attention. The findings of this study suggest that efforts to limit the requirement to pool decision-making would be most prospective. The potential for doing this is, perhaps, illustrated by the coexistence option to establish production zones. Production zones do have an establishment burden and this does require negotiation with neighboring farmers. However, once established, the need for further annual notifications of planting intentions and negotiations over planting dates and choice of cultivars is completely eliminated. Reforms to coexistence measures directed at encouraging the establishment of production zones, including reducing the administrative burden associated with organizing and operating them, would seem to offer obvious benefits.

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