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How Latent Attitudes Affect Farmers' Preferences for Genetically Modified Seeds: The Case of Small Corn Growers in Brazil

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The study analyzes how latent attitudes affect farmer preferences for GM corn seeds. Results are based on a survey of corn growers in the main producing regions of Brazil. Using factor analysis, the study identifies latent attitudes related to farmers' familiarity with GM technology; environmental concerns; trust in scientific research; and risk perception of pests, weeds, prices, and climate instability. Next, the impact of these latent attitudes on the stated preferences for GM seeds is estimated using conjoint analysis. Results highlight that, besides economic benefits, farmers' preferences for GM seeds can also be affected by more general attitudes, many of them reflecting values influenced by ideological and ethical concerns.

Key words: conjoint analysis, factor analysis, GM, revealed preferences, stated choice, stated preferences.

Introduction

The commercial liberalization of genetically modified (GM) corn cultivars in Brazil began in 2007; this began the diffusion process of varieties resistant to pest insects in the 2008/09 crop in regions of large production. The diffusion rate for the 2008/2009 crop was estimated at 19% and was closer to 70% for 2011/12 (Galvao, 2012). Corn production plays an important socioeconomic role among large and small farmers in Brazil (Miranda, Duarte, & Garcia, 2012), and GM cultivars have shown higher efficiency in comparison to conventional ones in this country, as well as reducing risks and increasing productivity (Pavão & Ferreira-Filho, 2011). Studies also highlight the environmental benefits of GM crops, such as reduced pesticide application, less soil erosion and compaction, and reduced fossil fuel consumption as a result of less use of tractors and greater resistance to adverse environmental conditions (Morse, Bennett, & Ismael, 2006; Nelson & DePinto, 2001).

The meaningful socioeconomic and environmental impacts of the GM cultivars have raised important questions about their adoption by interested socioeconomic groups. Studies usually highlight consumers' perceptions and purchase intentions toward GM products (a review of the main studies is presented by Smale et al., 2009). More scarce are the studies highlighting farmer preferences for GM seeds (Breustedt, Muller-Scheebel, & Latacz-Lohmann, 2008; Chong, 2005; Kondoh & Jussaume-Jr., 2006; Qaim & De Janvry, 2003). A relevant point in these analyses is that, besides economic benefits, preferences can also be affected by more general attitudes, many of them directly influenced by ideological and ethical concerns (Bredahl, 2001; Chen & Li, 2007; Martinez-Poveda, Molla-Bauza, Gomis, & Martinez, 2009; Rodríguez-Entrera, Salazar-Ordóñez, & Sayadi, 2013). While there are many studies addressing the impacts of attitudes on GM acceptance among consumers in developed and developing countries (for example, Angulo & Gil, 2007; Cook, Kerr, & Moore, 2002; Kikulwe, Wesseler, & Falck-Zepeda, 2011; Krishna & Qaim, 2008; Quan, 2002), there is still little research on the producer side (Areal, Riesgo, & Rodriguez-Cerezo, 2011; Birol, Villalba, & Smale, 2008; Cook & Fairweather, 2003; Skevas, Kikulwe, Papadopoulou, Skevas, & Wesseler, 2012).

This article analyzes how attitudes affect farmers' stated and revealed preferences for GM seeds. Specifically, it examines the case of small corn growers in Brazil. Special attention is given to the characteristics that differentiate growers of genetically modified (GM) corn—*Bacillus thuringiensis* (Bt) and herbicide tolerant (HT)—and non-genetically modified corn (non-GM)—Hybrid and Variety. The hypothesis under analysis is that, besides economic motivations, more general beliefs, such as attitudes toward the environment and scientific research, may also affect farmer preferences for GM seeds.

The paper contributes to the literature in three ways. First, it is the first applied economics study to investigate the determinants of GM adoption among farmers in Brazil, the fifth-largest agriculture producer in the world.[1] Second, this study adds to the growing literature that employs the choice experiment method to estimate

1. *Estimates based on the total value added of the agriculture sector in 2010 (World Bank, n.d.).*

the role of attitudes on stated preferences for GM technology (Louviere, Hensher, & Swait, 2000). Third, it provides important elements to orient decision-making on biotechnology policies for the agricultural sector in Brazil, especially those aimed at small farmers in less developed regions. While supporters of genetic engineering attest to its relevance in addressing the problems of food insecurity and malnutrition in developing regions, opponents claim that it may worsen environmental damage, poverty, and hunger, and lead to a corporate takeover of traditional agricultural production systems (Food and Agriculture Organization of the United Nations [FAO], 2004). Since farmers' acceptance of GM technology will be decisive for the future of GM adoption, understanding the main determinants of these preferences is essential to the future of research and agricultural development policies.

Attitudes Toward GM Products

Attitudes are recognized as one of the main factors guiding human behavior (Fishbein & Ajzen, 1975). Since behavioral intentions are strongly related to peoples' choices in the market, attitudes are also expected to influence their preferences and purchase intentions for several products, including GM foods (Bredahl, 2001). This hypothesis has been extensively tested in the case of consumer preferences for GM foods in developed and developing nations (meta-analyses are presented by Costa-Font, Gil, & Traill, 2008; Lusk, Mustafa, Kurlander, Roucan, & Taulman, 2005; Smale et al., 2009). Results suggest, for example, that attitudes are more positive and consumers are more likely to accept GM food in developing countries due to a more urgent need for food availability and nutritional content, as well as lower levels of perceived risk (Curtis, McCluskey, & Wahl, 2004). On the supply side, attitudes and beliefs may also influence intentions and actions toward the adoption of GM seeds (Cook & Fairweather, 2003). But, in this case, farmers' attitudes toward GM products seem to be mainly driven by economic expectations, such as higher incomes or decreased production costs due to reduced use of insecticides (Areal et al., 2011; Skevas et al., 2012).

Different approaches have been proposed to model the links among behavioral intentions, attitudes, and beliefs and their impacts on preferences for GM foods (Bredahl, 2001; Chen & Li, 2007; Rodríguez-Entrena et al., 2013). These models are mainly based on the Theory of Planned Behavior (Ajzen, 1991), an extension of Fishbein's multi-attribute attitude model (Fishbein, 1963). Among the factors identified as primary determinants of GM purchase intentions were prior knowledge of GM technology; trust in institutions; perceived risks; and general attitudes toward the environment, scientific research, and technology.

The relation between education and knowledge and its impact on popular acceptance of GM foods is a relevant issue for those interested in implementing policies oriented toward GM adoption (House et al., 2004). Prior knowledge about the costs and benefits of GM technology—which is related to different histories of media coverage, scientific literacy, and trust in regulatory procedures—tends to affect public perceptions and, thus, reflect cultural sensitivity to GM technology (Gaskell, Bauer, Durant, & Allum, 1999). Limited knowledge about GM technology may also heighten risk perception and reduce acceptance of GM foods (Costa-Font et al., 2008).

Individuals with little or total lack of knowledge about a new technology are more likely to rely on experts and institutions that regulate the use of new technologies (Chen & Li, 2007). As a result, trust in institutions promoting innovations and regulating risks tends also to affect public attitudes toward GM technology (Siegrist, 2000). Populations with low levels of trust in scientists and regulators tend to misperceive the risks and uncertainties and be more influenced by the exaggerated claims of those opposing GM products (Lang & Hallman, 2005). Studies suggest, for example, that trust in the biotech industry and in regulatory procedures is an important factor in explaining the differences in GM acceptance between Europeans and Americans (Costa-Font et al., 2008; Gaskell et al., 1999).

Prior knowledge of and trust in institutions providing information on biotechnology will influence perceived risks, which, in turn, are essential in understanding involvement in and acceptance of GM products (Sjoberg, 2000). Producers tend to be more likely to accept GM technology than consumers, since they are the first to perceive its economic benefits, such as increased productivity and lower use of pesticides (Martinez-Poveda et al., 2009). Since this technology tends to present increasing returns to scale, producer preferences would be especially positive among large farmers and highly specialized farmers (Skevas et al., 2012). In turn, consumer acceptance is especially influenced by their perception of risks, which tends to be more direct than their perception of supposed benefits. Nevertheless, perception of risks and benefits may vary substantially among regions and agricultural conditions, such as threats of pests, diseases, and climate instability to which farmers are subjected.

Attitudes toward the use of GM products may also reflect fundamental beliefs directly related to more general attitudes, such as attitudes toward the environment, scientific research, and technology (Bredahl, 2001; Chen & Li, 2007). Special attention can be given to increasing environmental concerns, since that is a phenomenon likely to enhance public resistance to emerging technologies and affect preferences for GM products (Frewer, Hedderley, Howard, & Sheperd, 1997). Opposition to the use of GM food production has centered on the belief that such technology may pose unacceptable risks to the environment (Cook et al., 2002). In Brazil, for example, some rural organized movements that are very influential among small farmers vehemently oppose the use of GM crops, disseminating attitudes that may negatively affect preferences for biotechnology.

Material and Methods

Analyses were based on 300 questionnaires administered between June and August 2012 to corn growers in the main Brazilian production regions (50 questionnaires in the state of Bahia, 45 in the state of Goiás, 42 in Maranhão, 96 in Minas Gerais, and 67 in Santa Catarina). Since the main objective of this study is to analyze the preferences of small farmers, farmers with no more than 5 hectares are overrepresented (57% of the sample). Just for comparison, small farmers with no more than 5 hectares represented 33% of corn growers in the whole Brazilian population in the Agricultural Demographic Census of 2006.

Sample units were selected according to information provided by experts from EMBRAPA (Brazilian Agricultural Research Corporation), technicians, and representatives of regional cooperatives of corn producers. The sample was stratified according to the types of seeds mainly cultivated by corn growers in Brazil: i) Bt, GM seeds resistant to insects (*Lepidoptera*); ii) HT, GM seeds tolerant to the herbicides glyphosate and/or glufosinate ammonium; iii) hybrid, non-GM seeds produced by cross-pollinated plants; and iv) variety: conventional non-GM seeds. The types of farmers most frequent in the sample were those growing hybrid corn seeds in the largest share of their cultivated areas (99 producers, or 33%) and variety (86, or 29%). Producers cultivating GM seeds in the largest share of their areas represented 25% of the sample (76 producers) and were predominantly Bt growers (68 producers), since the use of the HT technology is still very rare in Brazil (8 producers in the sample). The other 39 farmers (13%) did not report the type of seeds they were cultivating. Although there is no accurate information about the distribution of the types of seeds in the population of corn growers in Brazil, the sample representativeness was considered reasonable by experts from EMBRAPA.

Respondents were asked to indicate the strength of agreement or disagreement with thirteen statements related to several concerns and perceptions. Factor analysis (FA) was then employed to identify latent attitudes toward GM that were related to these responses (Kim & Mueller, 1978). These latent factors were then used as explanatory factors in the conjoint analysis (CA; Louviere et al., 2000) in order to evaluate their marginal effects on the farmers' stated preferences for GM seeds.

Factor Analysis

FA was used to identify latent attitudes in relation to the environment, biotechnology, and institutions, as well as perceived risks in relation to weeds, pests, prices, and climate instability. First, 13 statements related to these themes were presented to the farmers, who evaluated their level of agreement in relation to each of them in a Likert scale varying from totally disagree (1) to totally agree (5) to the following statements:

1. Scientific research has improved agricultural production.
2. Scientific research has improved human life.
3. Humans have caused serious damage to the environment.
4. Agricultural production has caused serious damage to the environment.
5. The use of pesticides in agriculture has caused serious health problems.
6. There are corn seeds that are resistant to agricultural pests.
7. There are corn seeds that are resistant to herbicides.
8. There are corn seeds that are more productive than conventional ones.
9. Fluctuations in the price paid to the producer are always a factor of high risk in corn production.
10. Climate fluctuation is always a factor of high risk in corn production.
11. Fluctuations in the price of inputs are always a factor of high risk in corn production.
12. The rise of pests is always a factor of high risk in corn production.
13. The rise of weeds is always a factor of high risk factor in corn production.

Responses for these statements were then used in the FA to obtain *m* common factors *F* that could reasonably explain the total variability of the 13 observable variables *X*. In other words, FA assumes that each observable variable X_i is expressed by a linear combinations of unobservable and uncorrelated factors *F* (Kim & Mueller, 1978):

$$X_i = a_{i1}F_1 + \ldots + a_{im}F_m + d_iU_i\,, \quad (1)$$

where *a* is the factor loading and expresses the relationship between the observable variables and the unobservable factors *F*. Factors *F* are also called common factors, since they contribute to explain the variability of the *n* observable variables. Variables *U* are called unique factors, because each unique factor U_i affects only the variability of a single observable variable X_i and expresses the behavior not explained by the common factors.

The use of latent factors *F* instead of observable variables *X* has two main advantages: i) to reduce the number of variables and eliminate redundant information, since some observable variables may be strongly related to others; and ii) to attenuate the problems of multicollinearity in regression models (next step in the analysis), since factors are independent of each other.

The common factors *F* were obtained by principal component factor analysis (PCF) due to its operational simplicity and the analytical consistency of its results in this case. The number of factors (*m*) was defined based on the total variability explained by each factor (λ). This measure represents the discriminatory power of the j^{th} factor over all observable variables, which is represented in relative terms, i.e., as a percentage of the total variability of the observable variables (Cuadras, 1981).

The varimax technique of rotation was also used to facilitate the interpretation of the factors (Cuadras, 1981). This process of linear transformation provided new factors that made the relationship between the factors and the observable variables more clear and objective, with no impact on the explanatory power of these factors. All analyses were done using the *factor* routine in Stata.

Conjoint Analysis

The next step of analysis was to apply CA to evaluate how farmers estimate their preferences in terms of the corn production system. The variables of interest (dependent variables) were collected by asking farmers about their preferences for different characteristics of corn systems. The CA identified the determinants of the rank-ordered evaluations of corn systems based on the characteristics of the alternatives and the farmers.

Table 1. Corn attributes in the contingent ranking.

Type	Price
Bt	Lower (R$180/bag + R$80 royalty)
	Average (R$230/bag + R$80 royalty)
	Higher (R$280/bag + R$80 royalty)
HT	Lower (R$180/bag + R$80 royalty)
	Average (R$230/bag + R$80 royalty)
	Higher (R$280/bag + R$80 royalty)
Hybrid	Lower (R$110/bag)
	Average (R$130/bag)
	Higher (R$150/bag)
Variety	Lower (R$50/bag)
	Average (R$60/bag)
	Higher (R$70/bag)

Different formats of choice studies can be applied, for example contingent choice, contingent rating, and contingent ranking (González, Johnson, & Qaim, 2004). Contingent choice asks the interviewee to report a choice from a set of alternatives. This format provides weakly ordered data, since only one response does not allow a complete preference ordering (Louviere et al., 2000). In the rating format, the interviewee rates each set of alternatives on a pre-defined rating scale. Although data in this format are less weakly ordered than in the contingent choice, it makes very strong assumptions about human cognitive abilities (Louviere et al., 2000). We preferred contingent ranking, which asks consumers to rank a set of alternatives. This format provides a complete preference order, albeit with no information about differences in the degree of preferences.

In this contingent survey, respondents were asked to rank a set of alternatives describing different characteristics of corn production. Two attributes of interest were considered: *type* of corn and *price* (Table 1). The attribute *type* represents the four most commonly produced corns in Brazil: GM Bt, GM HT, Hybrid, and Variety. The attribute *price* expresses variations in the average price of seeds in Brazil: lower than average (between 15% and 20% lower), average value, and higher than average (between 15% and 20% higher). In the case of GM seeds, the payment of royalties (R$80/hectare) was also considered. These values were obtained through interviews with experts and represent maximum and minimum prices practiced in Brazil. Such a design would imply a total of 81 possible alternatives (3 prices for each type = 3^4), which were randomly distributed in sets of four alternatives for each interviewee.

Farmer preferences for each type of seed were modeled using the rank ordered probit model (ROP), or exploded logit model (Allison & Chtistakis, 1994). First, suppose U_{ij} represents the utility of the j^{th} choice to the i^{th} individual. It can be assumed that U_{ij} is a random variable with a systematic component η_{ij} and an unpredictable random component ε_{ij}, such that (Rodriguez, n.d.)

$$U_{ij} = \eta_{ij} + \varepsilon_{ij} \; . \tag{2}$$

In turn, the systematic utility η_{ij} can be modeled as a function of the characteristics of the farmers (column vector $\mathbf{x}_i$) and characteristics of the alternatives (column vector $\mathbf{z}_j$)

$$\eta_{ij} = \mathbf{z}_j\boldsymbol{\delta} + \mathbf{x}_i\boldsymbol{\beta}_j \; . \tag{3}$$

The coefficients in the row vector $\boldsymbol{\beta}_j$ express how the acceptance of the alternative j is affected by individuals' characteristics $\mathbf{x}$ and the coefficients in $\boldsymbol{\delta}$ express how the acceptance is influenced by the alternatives' characteristics $\mathbf{z}$. Since farmers' characteristics are assumed to affect the choice for each alternative j differently, the coefficients in vector $\boldsymbol{\beta}$ vary for each alternative j. In turn, the vector $\boldsymbol{\delta}$ is constant over alternatives.

Although utility U is not measurable in the contingent ranking experiment, the probability of choosing an alternative j in comparison with an alternative k can be predicted by a probabilistic model. Farmer i will choose alternative j in comparison to alternative k if U_{ij} is higher than U_{ik} . Thus, if Y_i represents the choice of the farmer i, the probability of choosing alternative j can be expressed by

$$\Pr(Y_i = j) = \Pr(U_{ij} > U_{ik}). \tag{4}$$

The next step is to define a model to represent the probability of choosing alternative j in comparison to alternative k. By making some assumptions about the distribution of the error term, ε_{ij}, that probability can be modeled by (Maddala, 1983)

$$\Pr(Y_i = j) = \frac{e^{\eta_{ij}}}{e^{\eta_{ik}}} \; . \tag{5}$$

Now, it must be considered that, in this choice experiment, the most preferred alternative is selected in a set of J alternatives. McFadden's model for the probability of choosing alternative j among the entire set of alternative is (Allison & Chtistakis, 1994)

$$\Pr(Y_i = j) = \frac{e^{\eta_{ij}}}{\sum_{k=1}^{J} e^{\eta_{ik}}} \; . \tag{6}$$

After the first choice j has been made, the probability that the farmer will choose alternative m among the remaining alternatives is

$$\Pr(Y_i = m) = \frac{e^{\eta_{im}}}{\sum_{k=1}^{J} e^{\eta_{ik}} - e^{\eta_{ij}}} \; . \tag{7}$$

Similar development is done for the remaining choices, subtracting, in this case, term $e^{\eta_{im}}$ from the denominator, and so on.

Besides the factors obtained by the FA, several variables were used as regressors in the choice model. Two dummy variables were used to discriminate the characteristics of the alternative types of seeds ($\mathbf{z}$):

1. *Lower*: 1 for price lower than the average value usually charged and 0 otherwise
2. *Higher*: 1 for price higher than the average value usually charged and 0 otherwise

The average price is used as reference in this analysis.

Additionally, 10 variables were considered to discriminate the farmers' characteristics ($\mathbf{x}$).[2]

1. *Area*: total area of cultivated corn in hectares
2. *D_Bt*: dummy variable that values 1 if farmer cultivates Bt corn and 0 otherwise
3. *D_HT*: dummy variable that values 1 if farmer cultivates HT corn and 0 otherwise
4. *D_Hybrid*: dummy variable that values 1 if farmer cultivates Hybrid corn and 0 otherwise
5. *D_Variety*: dummy variable that values 1 if farmer cultivates Variety corn and 0 otherwise
6. *Factor1-Factor5*: scores for the five common factors identified in the FA

2. *Other explanatory variables were also tested, although they showed no significant relation with the choice of the corn seed.*

Table 2. Row distribution of farmers (%) in relation to their questions for several statements.

Question	Totally agree	Partially agree	Neutral	Partially disagree	Totally disagree
1. Scientific research has improved agricultural production.	70.5	19.0	5.8	2.4	2.4
2. Scientific research has improved human life.	63.4	22.0	7.8	4.1	2.7
3. Humans have caused serious damage to the environment.	68.0	18.4	6.1	3.1	4.4
4. Agricultural production has caused serious damage to the environment.	32.9	27.7	7.5	9.6	22.3
5. The use of pesticides in agriculture has caused serious health problems.	73.2	11.3	6.5	2.4	6.5
6. There are corn seeds that are resistant to agricultural pests.	71.4	5.8	11.2	6.1	5.4
7. There are corn seeds that are resistant to herbicides.	66.9	8.5	14.7	3.8	6.1
8. There are corn seeds that are more productive than conventional ones.	79.3	8.8	6.3	1.7	3.9
9. Fluctuations in the price paid to the producer is always a factor of high risk in corn production.	61.6	10.9	7.5	3.7	16.3
10. Climate fluctuations are always a factor of high risk in corn production.	85.4	9.5	1.0	1.4	2.7
11. Fluctuations in the price of inputs is always a factor of high risk in corn production.	72.5	8.8	6.4	4.4	7.8
12. The rise of pests is always a factor of high risk in corn production.	69.8	17.0	3.1	5.4	4.8
13. The rise of weeds is always a factor of high risk factor in corn production.	58.3	18.8	3.8	9.7	9.4

Source: Research data

It must be highlighted that using dummy variables to represent farmers' use of a particular type of seed (revealed preferences) in explaining farmer choices for different types of seeds (stated preferences) may generate endogeneity bias. Two models were fitted to test the consistency of the estimates—a restricted and an unrestricted model. The unrestricted model (Model 1) uses all controlled variables, and the restricted model (Model 2) did not consider the dummies *D_Bt*, *D_HT*, *D_Hybrid*, and *D_Variety*.

Maximum likelihood estimations for the coefficients β and δ in Model 7 were obtained using the *asroprobit* routine in Stata.

Results

Farmers' Attitudes

The level of agreement of the farmers in relation to the 13 statements of analysis is presented in Table 2. Results highlight that the great majority of the farmers totally or partially agree with the statement that scientific research has improved human life (Question 2, with 85% agreement, total or partial) and agricultural production (Question 1, with 89% agreement). They also tend to agree that pesticides cause negative impacts on human health (Question 5, with 85% agreement). On the other hand, the statement that agriculture causes serious damage to the environment presented a lower level of agreement (Question 4, with 32% disagreement, total or partial).

There is a relatively high rate of knowledge about the types of corn seeds that are resistant to pests (Question 6, with 77% agreement, total or partial), herbicides (Question 7, with 75%) and, in particular, about those that are more productive than conventional ones (Question 8, with 88%). This is an interesting result, since just 25% of the small farmers represented in the sample actually use GM seeds.

Climate instability is seen as the main source of risk in corn production (Question 10, with 95% agreement). Corn-producing regions are large and heterogeneous in Brazil, and they are differentially and frequently affected by cold fronts (South region) and prolonged droughts (especially in the Northeast region).

Pests, diseases, and weeds that affect the corn crop are also diverse, varying according to the soil, climatic conditions, cropping systems, and local biotic factors

Table 3. Eigenvalues and variance explained by each common factor.

Factor	Eigenvalue	Proportion	Cumulative
1	2.429	0.187	0.187
2	1.807	0.139	0.326
3	1.400	0.108	0.434
4	1.291	0.099	0.533
5	1.192	0.092	0.625
6	0.890	0.069	0.693
7	0.755	0.058	0.751
8	0.698	0.054	0.805
9	0.609	0.047	0.852
10	0.584	0.045	0.897
11	0.522	0.040	0.937
12	0.425	0.033	0.969
13	0.398	0.031	1.000

Source: Research data

(EMBRAPA, 2010). Among these, pests appear to present the greatest risk in corn production (Question 12, with 87% agreement).

Answers were then scored from 1 (totally disagree) to 5 (totally agree) and used as observable variables in the FA. Five common factors were selected, based on the discriminatory power of each factor and on the analytical consistency of the latent attitude represented by each factor. In relation to the discriminatory power, each of these 5 factors presented an eigenvalue higher than one, which means a marginal contribution higher than 8% (1/13), and all them together represented a considerable share (62.5%) of the total variability of the 13 original variables (Table 3).

Five factors were also necessary to explain consistently the structure of correlations among the 13 observable variables. All of them present strong to moderate correlations (higher than 0.6) with the 13 observable variables (Table 4). As a result, all observable variables have relatively low variances due to the unique factors, or *uniqueness* (0.5 or lower).

Based on the values of the rotated factor loadings, each factor could be interpreted as the following latent attitudes.

Factor 1: Environmentalism. This is the factor that most discriminates the total variability of the 13 observable variables (19%). It has a strong and positive relation with the level of agreement with the statement that the use of pesticides has caused serious health problems (Variable 5) as well as the statement that agriculture and the humans have caused serious environmental damages (Variables 3 and 4). Thus, the higher the value of this factor, the higher the concern about the impacts of human life and agricultural production on the environment.

Factor 2: Familiarity with GM Seeds. This factor discriminates 14% of the total variability of the observable variables (second-highest value). It has a strong and positive relation with the level of agreement with the statement that there are herbicide tolerant corn seeds (Question 7), corn seeds resistant to agricultural pests (Question 6), and corn seeds that are more productive than conventional ones (Question 8). Thus, the higher the value of this factor, the higher the knowledge about the existence of GM seeds and other more productive varieties.

Factor 3: Trust in Scientific Research. This factor discriminates 11% of the total variability. It has a strong and positive relation with the level of agreement that scientific research has improved agricultural production (Question 1) and human life (Question 2). Thus, the higher the value of this factor, the higher the level of trust in scientific research.

Factor 4: Risk of Price and Climate Instability. This factor discriminates 10% of the total variability of the observable variables. It has a strong and positive relation with the level of agreement that the instability of the price of inputs, climate, and prices paid to producers represent high risks to corn production (Questions 9, 10, and 11). It can then be assumed that the higher the value of this factor, the higher the risk perception in relation to price and climate instability.

Factor 5: Risk of Pests and Weeds. This factor discriminates 9% of the total variability and has a strong and positive relation with the agreement that pest and weeds represent high risks in corn production (Questions 12 and 13). Thus, the higher the value of this factor, the higher the perception of risks of pests and weeds in corn production.

Factor scores vary substantially according to farmer type (Table 5). First, attitudes toward environmentalism (Factor 1) significantly discriminate Bt farmers. These farmers tend to show a lower level of environmental concern in comparison to other farmer types. As would be expected, the degree of familiarity with GM seeds (Factor 2) is higher among those farmers cultivating GM seeds. In turn, farmers cultivating Variety seed show a lower level of familiarity with GM technology.

Table 4. Rotated factor loadings and unique variances.

Question	Factor1	Factor2	Factor3	Factor4	Factor5	Uniqueness
1	-0.036	0.136	0.825	0.048	0.111	0.285
2	-0.009	0.016	0.848	0.061	0.008	0.277
3	0.725	0.004	0.236	0.144	-0.183	0.365
4	0.772	0.024	-0.128	-0.027	0.157	0.361
5	0.740	-0.013	-0.125	-0.101	0.152	0.403
6	-0.010	0.708	0.260	0.231	-0.065	0.374
7	0.050	0.832	-0.074	0.044	-0.063	0.294
8	-0.073	0.622	0.220	0.007	0.303	0.468
9	-0.022	-0.023	0.110	0.680	0.129	0.508
10	0.050	0.068	-0.017	0.641	0.203	0.541
11	-0.011	0.171	0.069	0.813	-0.081	0.298
12	0.026	0.088	-0.001	0.024	0.833	0.298
13	0.132	-0.161	0.173	0.076	0.715	0.411

Source: Research data

Table 5. Average factor scores and pairwise comparisons according to farmer type.[1]

	Farmer type*			
Factor	Bt	HT	Hybrid	Variety
1	-0.611	0.387	0.060	-0.183
	B	A	A	A
2	0.414	0.595	0.015	-0.549
	A	A	B	C
3	0.122	-0.455	0.126	-0.215
	A	B	A	B
4	0.315	0.250	0.046	-0.454
	A	A	A	B
5	0.094	-0.185	-0.064	0.012
	A	A	A	A

Source: Research data.

[1] Values with the same letter (A, B, or C) are statically equal at 10% significance level by Duncan's test

** Farmers cultivating more than one seed type were classified according to the one more representative in their growing area.*

Trust in scientific research (Factor 3) is higher among Bt and Hybrid farmers, and is lower among HT farmers. Although the latter group also uses GM seeds, their revealed preferences seem to be more motivated by reasons other than the trust in the benefits of science to agriculture and human life. This would be especially true in regions with problems of weed infestation or shortage of labor, since HT seed gives farmers much more flexibility in terms of the timing and type of weed control (Fulton & Keyowski, 1999).

The risk perception of climate and price instability (Factor 4) is significantly lower for Variety farmers, which could partially justify their choices for seeds with lower resistance and productivity. In turn, there is no relevant pattern of relationship between the type of production and the risk perception of pests and weeds (Factor 5). This result can be attributed to the huge diversity of risks associated with agricultural production among these types of growers in Brazil.

Stated Preferences

This second step of analysis estimates the determinants of the farmers' stated preferences based on their rank-ordered evaluations for the type of corn seed that they were more willing to adopt. The interest variable in the ROP is the probability of choosing a specific alternative (type of seed) instead of Bt seed. For each farmer, four ranked choices of corn seeds were available (Bt, HT, Hybrid, and Variety), providing multiple pairs of comparisons.

Explanatory factors are represented by both characteristics of the alternatives and characteristics of the farmers (see description in the section on Conjoint Analysis). In order to evaluate the impacts of endogeneities, as high collinearity between the type of production and the latent factors, two ROP regression models were fitted. The unrestricted model (Model 1) uses all control variables described in the Conjoint Analysis section, while the restricted model (Model 2) did not consider the dummies for the types of production. Since Bt corn was chosen to be used as the reference of analysis, positive coefficients mean higher preferences for alternative j in comparison to Bt seed. The alternatives j are

Table 6. Maximum likelihood estimates for the rank ordered probit model.

		Model 1				Model 2			
	Variable	**Coef.**	**SE**	**z**	**P>|z|**	**Coef.**	**SE**	**z**	**P>|z|**
Alternatives									
	Lower	-0.073	0.142	-0.51	0.607	-0.049	0.142	-0.34	0.730
	Higher	-0.118	0.129	-0.91	0.361	-0.075	0.129	-0.58	0.563
Farmers									
HT	**Constant**	0.061	0.240	0.25	0.800	-0.096	0.121	-0.79	0.427
HT	**Area**	-0.008	0.004	-2.20	0.028 **	-0.010	0.004	-2.66	0.008 ***
HT	**D_Bt**	-0.594	0.332	-1.79	0.074 *				
HT	**D_HT**	-0.025	0.580	-0.04	0.966				
HT	**D_Hybrid**	-0.023	0.255	-0.09	0.928				
HT	**D_Variety**	-0.122	0.272	-0.45	0.653				
HT	**Factor1**	-0.127	0.121	-1.05	0.295	-0.070	0.116	-0.60	0.547
HT	**Factor2**	-0.020	0.114	-0.17	0.862	-0.045	0.107	-0.42	0.676
HT	**Factor3**	0.021	0.110	0.19	0.852	0.018	0.108	0.17	0.865
HT	**Factor4**	0.167	0.114	1.46	0.144	0.156	0.111	1.40	0.161
HT	**Factor5**	-0.139	0.109	-1.28	0.202	-0.135	0.107	-1.26	0.208
Hybrid	**Constant**	1.093	0.365	3.00	0.003 ***	0.863	0.205	4.21	0.000 ***
Hybrid	**Area**	-0.017	0.005	-3.19	0.001 ***	-0.025	0.006	-4.20	0.000 ***
Hybrid	**D_Bt**	-2.081	0.505	-4.12	0.000 ***				
Hybrid	**D_HT**	-2.971	0.953	-3.12	0.002 ***				
Hybrid	**D_Hybrid**	-0.039	0.372	-0.11	0.916				
Hybrid	**D_Variety**	0.648	0.407	1.59	0.111				
Hybrid	**Factor1**	-0.066	0.173	-0.38	0.703	0.130	0.179	0.73	0.467
Hybrid	**Factor2**	0.350	0.167	2.09	0.037 **	0.029	0.164	0.17	0.861
Hybrid	**Factor3**	-0.281	0.166	-1.70	0.090 *	-0.302	0.175	-1.72	0.085 *
Hybrid	**Factor4**	0.490	0.168	2.93	0.003 ***	0.297	0.169	1.76	0.079 *
Hybrid	**Factor5**	-0.224	0.160	-1.39	0.163	-0.207	0.168	-1.23	0.217
Variety	**Constant**	0.642	0.463	1.39	0.166	0.079	0.256	0.31	0.759
Variety	**Area**	-0.022	0.008	-2.98	0.003 ***	-0.036	0.009	-4.15	0.000 ***
Variety	**D_Bt**	-3.620	0.756	-4.79	0.000 ***				
Variety	**D_HT**	-3.527	1.234	-2.86	0.004 ***				
Variety	**D_Hybrid**	-0.583	0.495	-1.18	0.239				
Variety	**D_Variety**	1.071	0.534	2.01	0.045 **				
Variety	**Factor1**	0.107	0.238	0.45	0.654	0.444	0.252	1.76	0.078 *
Variety	**Factor2**	0.098	0.220	0.45	0.656	-0.407	0.229	-1.78	0.076 *
Variety	**Factor3**	-0.362	0.217	-1.67	0.095 *	-0.447	0.233	-1.92	0.055 *
Variety	**Factor4**	0.682	0.226	3.02	0.003 ***	0.366	0.229	1.60	0.109
Variety	**Factor5**	-0.698	0.227	-3.07	0.002 ***	-0.630	0.237	-2.66	0.008 ***

Source: Research data

SE=standard error

****, **, * Significance at 1%, 5%, and 10% level, respectively* described in the first column (vertically aligned) of Table 6.

The models fitted the data well, with goodness of fit measures (*log simulated-likelihood* statistic) significant at the 0.1% level. The maximum likelihood estimates for the coefficients (Equation 3) are presented in Table 6. The estimates are largely consistent, since they tend to present similar signals in both models. Some significances are different, which reflect the presence of multicollinearity among type of production and latent factors in the unrestricted model.

First, the insignificant estimates for the coefficients related to variables *Lower* and *Higher* suggest that small changes in the price have no significant effect on the stated preferences for the type of corn seed. Two factors may help explain these results: i) the low variability of the prices presented in the survey, which were based on minimum and maximum prices suggested by experts; and ii) the low cost of seeds in comparison with other fixed costs incurred by corn growers in Brazil. In other words, the price of seeds should have an insignificant impact on the total cost of production and the farmers' choices for different types of seeds.

The negative coefficients estimated for the variable *Area* highlight that producers with larger cultivated areas are more likely to adopt Bt seed. The estimates are lower for alternatives *Hybrid* and *Variety* (-0.017 and -0.022, respectively), meaning that area is more important in making the choice between Bt and non-GM seeds (*Hybrid* and *Variety*) than between Bt and HT seeds. These results may suggest that farmers visualize increasing returns to scale using GM seeds, due, for example, to increasing productivity and reducing costs of pesticides that just outweigh the cost of changes for larger areas.

The coefficients estimated in Model 1 for the dummy variables associated with the type of corn cultivated in the farm (*D_Bt*, *D_HT*, *D_Hybrid*, and *D_Variety*) suggest that the revealed choice for GM corn has a positive impact on the stated preferences for this kind of seed. For example, the negative and significant coefficient estimated for the *D_Bt* variable in the alternative *Hybrid* suggests that Bt farmers are less likely to adopt Hybrid than Bt seeds. Moreover, since these estimates are higher (in module) for *D_Bt* and *D_HT* variables among non-GM alternatives (*Hybrid* and *Variety*), the results suggest that farmers cultivating GM seeds are less likely to choose a non-GM seed than the other way round, e.g., they are more averse to changes than non-GM farmers.

Attitudes also showed significant impacts on the choice for GM or non-GM seeds. For example, the coefficients related to Factor 4 are positive and significant for non-GM alternatives, except in Model 2 for alternative *Variety*. This means that, holding other variables constant, farmers with a higher risk perception of price and climate instability are more likely to adopt non-GM seeds (*Hybrid* or *Variety*). In other words, risk perception of climate and price instability tends to negatively affect the choice for GM seeds.

The coefficients for Factor 3 are negative and significant (at 10%) in Models 1 and 2 for non-GM alternatives. This means trust in scientific research is negatively related to the choice of non-GM seeds. In other words, farmers who trust scientific research are more likely to adopt GM seeds. This is an expected result, since individuals with total or partial lack of knowledge about a new technology would be more likely to rely on the opinion of experts and institutions to make their choices.

Moreover, the risk perception of pests and weeds (Factor 5) tends to affect negatively the choice of Variety seed in comparison to Bt seed. The coefficient for this factor is only significant (and negative) for alternative *Variety*. In fact, the benefits of Bt would be enhanced by the presence of pests, which clearly explain farmer preferences for more resistant seeds.

Factor 1 also presents significant impacts on farmers' stated preferences, being relevant to the choice between Variety and Bt seeds. The negative coefficient in Model 2 for alternative *Variety* suggests that the higher the level of environmentalism, the higher the propensity to adopt Variety corn in comparison with Bt corn. This effect is non-significant in Model 1, which may be due to the strong relation between environmentalism attitudes and farmers' revealed preferences represented by the binary variables.

Finally, Factor 2 showed opposite effects on choices between Hybrid and Variety seeds when compared to Bt seed. First, the positive and significant estimate for Factor 2 in Model 1 for alternative *Hybrid* suggests that Hybrid farmers are less willing to choose a Bt seed if they are familiar with their existence. That result may reflect the perception about the insufficient net benefits of a change between Hybrid and Bt seeds. In turn, the positive and significant estimate for Factor 2 in Model 2 for alternative *Variety* suggests that the higher the familiarity with GM seeds, the lower the propensity to adopt Variety seed in comparison to Bt seed. In other words, the choice for a conventional seed (variety) would be especially due to the lack of information about the existence of GM seeds.

Discussion and Final Considerations

This study provided elements to understand how the revealed and stated preferences of corn farmers in Brazil are affected by attitudes toward GM technology. Results highlight that, besides economic benefits, general attitudes may also affect farmers' behavior intentions and, thus, the acceptance of GM technology.

First, results showed that corn farmers in Brazil tend to view the role of scientific research on human life and agriculture optimistically. However, they are more skeptical in relation to the impacts of agriculture on the environment and more pessimistic about the impacts of pesticides on human health. Threats of pests and climate instability, which vary substantially among regions in Brazil, are seen as the main sources of risk in corn production.

Many attitudes related to the acceptance of GM technology represent individuals' values and are not directly observed. However, latent attitudes identified by the FA helped in understanding farmer preferences for GM seeds. FA identified common factors related to farmers' familiarity with GM seed, environmentalism, trust in scientific research, and perceived risk of prices, climate instability, pests, and weeds.

First, GM farmers are less likely than non-GM farmers to change the type of seed they cultivate, which may reflect their perceptions of the real benefits of GM technology. Moreover, as would be expected, there is a positive relation between knowledge of GM technology and the use of GM seeds. Limited knowledge about GM technology tends to increase perceived risk and reduce the acceptance of GM products (Costa-Font et al., 2008).

Trust in scientific research tends to increase the willingness to accept GM seeds. Public acceptance of technology goes hand-in-hand with trust in and credibility of science and those scientific institutions providing information and regulating risks. In turn, public recognition of the tangible benefits of new technologies will mediate perceptions of associated risk and thus will also affect acceptance of GM products.

The association between farmers' choices and perceived risk of climate and price instability showed contradictory results for revealed and stated preferences. First, revealed preferences suggest that this type of risk perception is lower among *Variety* farmers. This is an expected result and suggests that risk aversion is related to the choice of more resistant seeds. Prolonged droughts, that are usual in some Brazilian regions, can favor the emergence of pests that are controlled by the Bt toxin. In turn, holding constant farmers' characteristics, those farmers with higher levels of risk perception of price and climate instability are less likely to accept GM seeds. Once we control for the type of seed cultivated, the negative relation between this perception of risk and stated preferences for GM seed should express higher sensibility to the royalties of the GM seeds.

Farmers that cultivate GM corn tend to be more environmentally skeptical than non-GM farmers. Moreover, the lower the level of environmental concerns, the higher the propensity to adopt Bt corn in comparison to Variety corn. These results deserve two main considerations. First, it suggests that, besides economic factors, farmers also consider the impacts of their choices on the environment and the consequences for future generations. Second, and most importantly, it highlights the need to stimulate research on biotechnological safety to oppose the popular belief that GM practices may impose risks on environment and human health, a notion that is strongly disseminated by social groups that influence policies for small farmers in Brazil.

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