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Categories of GM Risk-Benefit Perceptions and Their Antecedents

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The stated benefits and perceived risks of genetic modification (GM) cover very diverse issues, such as food safety, world food security, and the environment, that may differentially affect consumer acceptance. In this research, we hypothesize that consumers perceive up to eight dimensions: risks to business (farmers, agribusiness, etc.), benefits to business, risks and benefits to the environment, risks and benefits to the developing world, and risks and benefits to self and family. Moral concerns are also recognized. Using data collected in 2002 in the United States, France, and the UK, we investigate these different dimensions. Second, we analyze the extent to which the dimensions of risk-benefit perceptions can be explained by general attitudes widely used to explain food purchase behavior (such as general attitude to the environment, to technology, etc.), as well as by perceived knowledge of GM, level of education, and trust in various sources of information. In all locations, the majority of consumers only perceive a medium level of risk from GM products. Attitude to technology is the most important attitude variable—those with a positive attitude to technology in general also have a positive attitude to GM technology. More Americans than Europeans fall into this category. Those who trust government and the food industry tend to think GM technology is less risky, whereas those who trust activists believe the opposite. Americans are more trusting of the former, Europeans of the latter. Level of education is positively associated with benefit perceptions and negatively associated with moral concerns. Location continues to play a limited independent role in explaining perceptions even after these factors have been taken into account.

Key words: attitudes, developing world, environment, health, knowledge, moral concerns, trust

Introduction

Potential benefits and risks associated with genetic modification (GM) go beyond food safety and encompass issues such as the impact of GM products on the environment and the developing world. Potential consumers may also be concerned about moral and ethical aspects of GM technology. It is likely that these different dimensions differentially affect consumer acceptance of GM in food production. In this paper, we explore whether consumers really perceive different dimensions of risks and benefits[1] and whether their perceptions can be explained by their general attitudes (to the environment, technology, food quality) and to trust in food chain actors, knowledge of GM, and level of education. We are aware that people may exaggerate risk perceptions in surveys (e.g., see Al-Sendi, Shetty, & Musaiger, 2004; Rimal, Fletcher, & McWatters, 1999, Yeung & Morris, 2001), but in this paper our interest is in relative risk perceptions (e.g., risk to the environment vs. risk to food safety), so this does not cause a problem. The information generated should be valuable to producers and policy makers interested in understanding and perhaps attempting to influence people's perceptions of GM. It may also help in understanding differences in perceptions between EU and US consumers; to this end, data were collected in various locations in the United States, UK, and France. Finally, we would also hope that the findings elaborated in this paper can be generalized to other products of other new technologies for which consumers have to weigh up risks and bene-

1. *In this paper, risk perception is considered as a psychological construct that may influence people's behavior rather than the probability associated with a random outcome, as used in an economics context. Perceived risk (and benefit) in the psychology literature are usually measured on a Likert scale between end-points represented by statements such as very risky and not at all risky (e.g., Alhakami & Slovic, 1994, Frewer, Howard, &Shepherd, 1997; Siegrist, 1999).*

fits, although it is unlikely that these will be identical across technologies.

Perceived Risks, Benefits, and Moral/ Ethical Concerns Associated with GM Foods

Research on perceived risks from food has traditionally focused on risks associated with food safety. Researchers have made use of Slovic's (1987) theory to explain why people exaggerate some risks (relative to the "true" objective risk) and underestimate others. Consumer acceptance involves a weighing up of risks and benefits (Frewer, 1999; Hoban, 1998). However, in the case of genetic modification, consumers' concerns and potential benefits extend beyond traditional food safety. Among the supposed advantages of GM are improved food safety, functional benefits to food (better taste, nutritional quality), environmental benefits (e.g. less pesticide use; Caulder, 1998; Grunert et al., 2001), and to satisfy growing world food demand. It has also been argued that any country failing to embrace GM methods risks becoming technologically backward and suffering falling international competitiveness (Food Standards Agency [FSA], 2003a, 2003b)—therefore, potential consumers may feel that they are supporting their own farmers and food manufacturers by supporting GM technology. But for each potential benefit, there is potential risk—safety may be lowered, quality reduced, the environment damaged, developing countries disadvantaged, and farmers and food manufacturers rendered subservient to multinational life science companies (Bredahl, Grunert, & Frewer, 1998; Morris & Adley, 2000; Perdikis, Kerr, & Hobbs, 2001). Consumers have also expressed concern about the "abuse" of living things for commercial benefit (FSA, 2003a, 2003b; Grunert, Bredahl, & Scholderer, 2003).

Past research has shown that there is an inverse association between consumers' perceived risks and perceived benefits (Alhakami & Slovic, 1994; Lloyd, Hayes, Bell, & Naylor, 2001; Siegrist, 1999), and it has been suggested that the negative correlation shows that people fail to consider the dimensions of risks and benefits separately (Alhakami & Slovic, 1994). In other words, those that perceive high risks would tend also to perceive low benefits from GM. However, it is perfectly reasonable to argue in favor of both high benefits and high risks—herbicide-tolerant or insect-resistant crops may require less herbicides and pesticides in production (good for the environment) but reduce biodiversity (bad for the environment). We investigate whether there is a case for aggregating perceived risks with (inversely scored) perceived benefits.

Scales to measure food risks and benefits from GM have not been widely tested and accepted, so they require some scale development. (For a discussion of scale development, see Henson & Traill, 2000.) Essentially, an immeasurable psychological construct (e.g., perceived food safety risk of GM) causes a number of measurable items (e.g., specific food safety concerns associated with GM), which can be measured in a questionnaire and combined to give a score for the strength of an individual's feeling with respect to the underlying construct. Based on our reading of the literature on consumer concerns and benefits (e.g., Baskshi, 2003; Pretty, 2001; Rowland, 2002; Smith & Skalnik, 2003; Wu, 2004), as well as discussions in the media and by industry, environmental, and consumer groups, we drew up a series of questions (items) grouped into nine categories: agricultural and food business risk, agricultural and food business benefit, risk to self and family, benefit to self and family, risk to the developing world, benefit to the developing world, environmental risk, environmental benefit, and moral/ethical concerns. Nine-point scales were anchored at the ends with the terms *strongly disagree* and *strongly agree*. Scale items[2] are shown in Appendix A.

Risk and Benefit Antecedents

Our intention is to examine whether people's GM risk-benefit perceptions can be explained by their general and food-related attitudes and by other variables expected to influence risk perceptions, such as knowledge (or perceived knowledge) of GM, trust in sources of information on GM products (government, industry, activists), and level of education (the ability to analyze information). We also investigate whether the anticipated American acceptance and European rejection of GM can be explained by these risk-benefit antecedents or if there remains a "cultural residual" that we are unable to explain.

Attitudes comprise a person's beliefs about an object, their feelings toward the object, and action tendencies with respect to the object (Ajzen & Fishbein, 1980). Relevant attitudes that have been used to explain food buying behavior include food neophobia (the ten-

2. *There is a possibility that the respondents might misinterpret the questions due to the complexity of the questionnaire (as suggested by one of the reviewers), however, this problem was not manifested during the pilot test.*

dency to avoid novel foods), attitudes to technology, attitudes to food quality, and attitudes to the environment. In our study we employ four scales: attitude to the environment, adapted from the New Environment Paradigm scale (Dunlap & van Liere, 1978); attitude to new foods, adapted from the Food Neophobia scale (Pliner & Hobden, 1992); attitude to technology, adapted from Hamstra (1991); and attitude to food quality, adapted from Steenkamp (1989).

People's general and food-specific attitudes alone will not completely explain their risk-benefit perceptions. They regularly seek and/or receive new information that they must process. Thus, risk-benefit perceptions are hypothesized to be related to people's trust in the source of information (see Verdurme, Gellynck, & Viaene, 2001). We measure the level of trust in government and the food industry and in activist groups such as environmental organizations. We anticipate that because government and the food industry promote a generally positive message about GM technology (e.g., FAO/WHO, 2000), people who trust these information sources will perceive lower risks and higher benefits. By contrast, environmental groups tend to paint a bleak picture of GM technology, so trust in these organizations should lead to higher risk and lower benefit perceptions.

It has been argued that ability to process information also influences awareness and potential attitudes; this ability is presumed to be related to level of education (Steenkamp, 1997; Zhong, Marchant, Ding, & Lu, 2002), although the direction of the effect is somewhat ambiguous, because level of education could result in a better capacity to identify risks as well as benefits (see Berrier, 1987; Hursti & Magnusson, 2002; Office of Technology Assessment, 1987; Steenkamp, 1997; Steward, 2000; Subrahmanyan & Sim Cheng, 2000).

Perceived knowledge about GM is also expected to have an influence on risk-benefit perceptions. It is hypothesised that people perceive risks that are familiar to them as lower than those that are unfamiliar (see Miller, 1998), suggesting a negative association between perceived knowledge and perceived risk.

Data Collection

The modelling and data collection are based on a joint US/UK project that enabled data to be collected in three American locations plus one location each in the UK and France. Data were collected during the third quarter of 2002[3] in Lubbock, Texas (n = 80), Long Beach, California (n = 47), Jacksonville, Florida (n = 39), and two locations in the EU: Reading, UK (n = 108) and Grenoble, France (n = 98). The locations were selected to provide diversity in geography, population, and culture.[4] In each of the five locations, marketing research companies were hired to recruit individuals for participation in the study. Recruitment was restricted to females between the ages of 25 and 65, because women remain the primary grocery shoppers (Progressive Grocer, 2002). Age restrictions were implemented to ensure that a disproportionate number of students or retirees, with relatively low opportunity cost of time, would not dominate the sample. Subjects were originally contacted by phone and offered $50 (or the equivalent in local currency) to participate in the study. Participants completed the questionnaire in rooms hired for the purpose.

Empirical Results

In this section we look first at the dimensions of risk-benefit perceptions, then at the hypothesised antecedents, and finally at the explanation of the risk-benefit perceptions by the antecedents.

Scales of Risk-Benefit Perceptions

Scale items are shown in Appendix A. We investigate various alternative propositions:

- Within each of the four categories of risks and benefits discussed in Section 2 (risks and benefits to agricultural and food businesses, to self and family, to the developing world, and to the environment), individuals who perceive high risks also perceive low benefits. If the (negative) correlation is sufficiently strong, risks and benefits can be aggregated (with reverse scoring) into single scales by category (e.g., composite environmental risk/benefit, etc.).
- Risks are positively correlated across category, as are benefits (e.g., individuals who think that risks to

3. *Piloting took place in April and May 2002.*

4. *Lubbock has a population of about 250,000 and is located in a predominantly agricultural area in the panhandle of Texas. In contrast, Long Beach is definitively urban, as it is located in Los Angeles County, which has a population of over 9.6 million. In terms of the number of residents, Jacksonville lies between Lubbock and Long Beach, with a population of about 790,000. The selected EU locations are roughly similar to Lubbock in terms of population. In addition, Lubbock, Reading, and Grenoble all have sizable universities. Reading is located approximately 60 kilometers west of London and has a population of about 250,000. Grenoble is located in southeast France and has a population of about 400,000.*

self and family are high also think risks to the environment, the developing world, and businesses are high; similarly with benefits). If so, the items can be aggregated into one composite risk scale and another composite benefit scale.

- Composite risks are strongly negatively correlated with composite benefits. If so, the items can be combined to form a single composite risk-benefit scale.[5]

In all cases, moral concerns are considered a separate category. Thus, items associated with this latent variable are not aggregated into any of the other scales.

There is no accepted single decision criterion for selecting an "optimal" scale. A combination of visual inspection, Cronbach's alpha,[6] inter-item correlations, and goodness-of-fit statistics in confirmatory factor analysis (CFA)[7] are used. Tables A1 through A8 show values for these various statistics. They provide no definitive answer, but the following are general observations:

- Risks and benefits are (statistically significantly) negatively correlated within each of the four categories of risks and benefits (Table A1). Risks are also (significantly) positively correlated across category, as are benefits. Risks are also (significantly) positively correlated with moral concerns.
- Although moral concerns are strongly correlated with other aspects of risk in the minds of those surveyed, we have kept them as a separate scale because they are of an intuitively different nature to the other categories of risk. However, on a purely statistical basis, a case could be made for combining moral concerns with other aggregate measures of risk.
- 0.70 is often considered a minimum acceptable level for Cronbach's alpha, but alpha tends to increase as the number of scale items increases. On this basis, Table A4 suggests that nine separate scales are too many (only *you and family risks*, *you and family benefits*, *developing world benefits*, and *moral concerns* have acceptable alphas). At the higher levels of aggregation of the items shown in Tables A5, A6, and A7, only the composite business risk/benefit fails the alpha test.
- Confirmatory factor analysis was employed to assess the goodness of fit of aggregating the items into two scales (all risk and benefit items combined, moral concerns); three scales (all risk items combined, all benefit items combined, moral concerns); and five scales (composite business risk/benefit, composite self and family risk/benefit, composite environmental risk/benefit, composite developing world risk/benefit, moral concerns). Results (Table A8) indicated that the overall model fit indices[8] were similar across the levels of aggregation, although the three-scale aggregation (all risks, all benefits, moral concerns) performed somewhat better than the other two.

Overall, we conclude that there is not a single unambiguously best level of aggregation of the various items into scales. We therefore proceed to investigate the characteristics of the three-scale aggregation (all risks, all benefits, moral concerns) and a four-scale aggregation (composite self and family risk/benefit, composite envi-

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5. *In this case, as under the first bullet point, reverse scoring is required to enable scale amalgamation.*
6. *Cronbach's alpha is used to assess the measurement reliability: the extent to which repeated measurements by the same method on the same subject produce the same result.* $\alpha = [N / (N - 1)] [1 - \Sigma\sigma_i^2/\sigma_T^2]$*; where* α *= Cronbach's alpha;* N *= number of items;* σ_T^2 *= variance of the total of all items;* $\Sigma\sigma_i^2$ *= sum of item variances. It ranges between 0 (indicating that items are completely uncorrelated and therefore cannot reliably be said to have been caused by the same underlying psychological construct) to 1 (if the items are perfectly correlated). An "optimal scale" has items that are highly but not perfectly correlated. Alphas above 0.7 but not much over 0.9 are considered ideal.*
7. *Confirmatory factor analysis was conducted using LISREL 8.30 in order to assess the validity of the proposed factor model. In other words, this statistical procedure assessed whether the proposed combination of items to represent the underlying factors is reasonable. The LISREL program produced several goodness-of-fit indices, including root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), and adjusted goodness-of-fit index (AGFI) to indicate whether the suggested factor model is a good fit of the existing data.*
8. *The overall model fit was assessed using the difference between the covariance matrix predicted by the model (implied covariance matrix) and the sample covariance matrix derived from the observed data (observed covariance matrix). Commonly used fit indices include the root mean squared error of approximation (RMSEA), the goodness-of-fit index (GFI), and the adjusted goodness-of-fit index (AGFI). These were utilized to avoid reliance exclusively on a single measure (Bagozzi & Baumgartner, 1994; Bollen & Long, 1992). Suggested thresholds for good fit are RMSEA < 0.10 (Schumacker & Lomax, 1996), GFI > 0.90, and AGFI > 0.80 (Gefen, Straub, & Boudreau, 2000).*

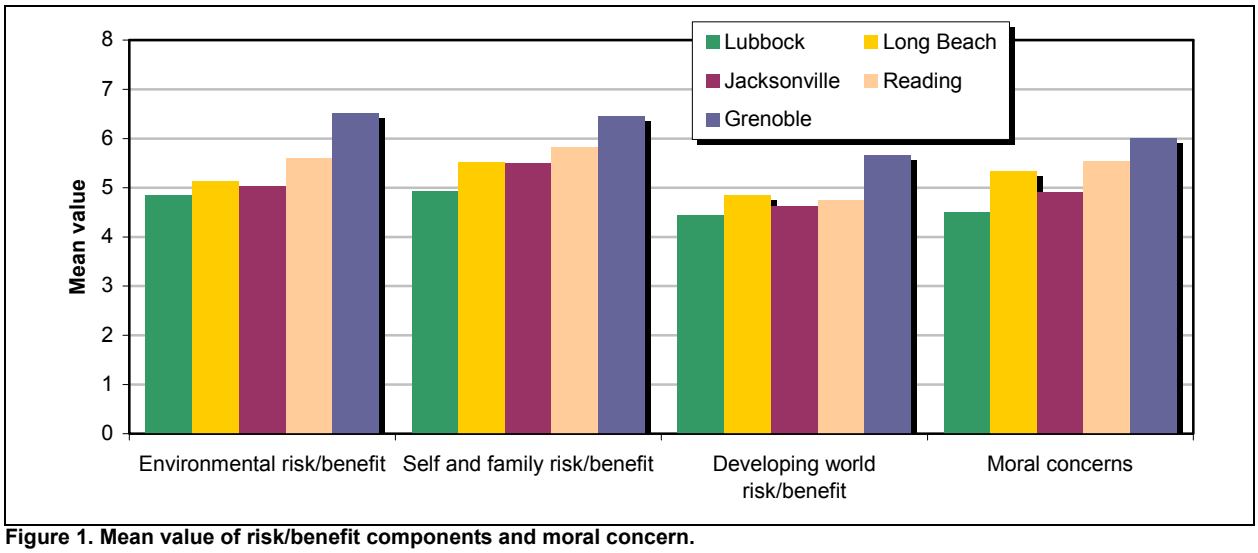

Figure 1. Mean value of risk/benefit components and moral concern.

ronmental risk/benefit, composite developing world risk/benefit, moral concerns). The poorly performing composite business risk/benefit is dropped.

Risk and Benefit Scale Values, Attitudes, Trust, and Knowledge

Figure 1 shows the mean values for the four-scale aggregation. Environmental risks, risks to self and family, and moral concerns are viewed as the most important problems associated with GM in all locations. There is surprisingly little difference in scores between Long Beach, Jacksonville, and Reading, but we learn that there are substantial differences between the French and Texans—this may not come as a monumental surprise![9] The mean values for all risks and all benefits of all respondents are 5.92 and 5.22, respectively. The French perceived most risks (mean value = 6.68) and least benefits (mean value = 4.48). Texans perceived least risks (mean value = 5.23) and most benefits (mean value = 5.89).

Table 1 shows the distribution of aggregate per-

Table 1. Distribution of aggregate perceived risks scores.

	Aggregate risk/benefit[a]			
	Low	Medium	High	Total
Lubbock	4 (5%)[a]	55 (71%)	17 (24%)	76
Long Beach	0	33 (81%)	8 (19%)	41
Jacksonville	2 (5%)	23 (62%)	12 (33%)	37
Reading	2 (2%)	76 (75%)	24 (23%)	102
Grenoble	0	47 (50%)	47 (50%)	94
Total	8 (2%)	234 (67%)	108 (31%)	350

[a] Low = scores 1–3; medium = scores 4–6; high = scores 7–9.
[b] Expressed as a percentage of the region total.

Table 2. Mean value of consumer trust.

	Trust in government and industry[a]	Trust in activist groups[b]
Lubbock	6.08	4.19
Long Beach	5.22	4.59
Jacksonville	5.42	4.08
Reading	4.64	4.82
Grenoble	4.04	5.50

Note. Measured on nine-point scale (1 = strongly distrust, 5 = neither trust nor distrust, 9 = strongly trust).
[a] Trust in government and industry was the average value of the scores obtained from the two questions: "The extent to which you trust or distrust information about genetic modification in food production from government agencies" and "The extent to which you trust or distrust information about genetic modification in food production from agricultural and food business."
[b] Trust in the information provided by activists was measured with the question "The extent to which you trust or distrust information about genetic modification in food production from activist groups."

9. *Post-hoc tests revealed that with the exception of moral concerns, the mean score of the respondents in Grenoble was significantly different from other regions in the five composite scales. The mean scores of business risk, environmental risk, and you and your family risk of those in Reading were significantly different from those in Lubbock, and the mean score of moral concerns was significantly different among Lubbock, Reading, and Grenoble, all at 0.01 level.*

Table 3. Results of regression analysis with four risk/benefit categories.

	Composite environmental risk/ benefit	Composite self and family risk/benefit	Composite developing world risk/benefit	Moral concerns
Constant	7.033***	6.401***	7.168***	4.490***
New environmental paradigm	.059	.140***	.065	.229***
Food neophobia	-.010	.034	.009	.129***
Food quality	.112**	.136***	.081	.136***
Technology	-.230***	-.230***	-.311***	-.211***
Trust in government & industry information	-.284***	-.299***	-.258***	-.248***
Trust in activist groups information	.101**	.111**	.130***	.057
Perceived knowledge	.007	-.077	-.096*	-.021
Level of education (0 = non-degree holder; 1 = degree holder)	.000	-.038	-.093*	-.170***
Region dummy 1 (Lubbock)	-.232***	-.259***	-.175***	-.083
Region dummy 2 (Long Beach)	-.169***	-.111**	-.092*	-.004
Region dummy 3 (Jacksonville)	-.160***	-.087	-.111*	-.022
Region dummy 4 (Reading)	-.179***	-.140**	-.261***	-.045
R^2	0.370***	0.410***	0.331***	0.333***
Significance test on dummies	**Intercepts difference (F1)**		**Slope difference (F2)**	
Composite environmental risk/benefit	$F1_{4,332} = 4.50$***		$F2_{32,300} = 1.21$	
Composite self and family risk/benefit	$F1_{4,332} = 4.99$***		$F2_{32,300} = 0.68$	
Composite developing world risk/benefit	$F1_{4,332} = 4.69$**		$F2_{32,300} = 1.18$	
Moral concerns	$F1_{4,332} = 0.57$		$F2_{32,300} = 1.07$	

*Note. *** significant at 0.01 level. ** significant at 0.05 level. * significant at 0.10 level.*

ceived risks/benefits (all risks and benefits with the exception of moral concerns aggregated). Although the French have the highest proportion of respondents who view aggregate perceived risks as high, even there half the sample considers risks to be only at a medium level. In other locations, a significant majority fall in this category, and overall two thirds of respondents consider risks to be medium. This should provide some reassurance to those keen to promote GM technology.

For the four general attitude scales, namely the New Environment Paradigm, food neophobia, food quality, and technology, scale reliability is good ($\alpha = 0.70$, 0.85, 0.86, and 0.81, respectively), except for the New Environment Paradigm, which is marginally acceptable, given the number of items employed. The New Environment Paradigm scale has been the subject of some debate in the recent literature (Dunlap, Van Liere, Mertig, & Jones, 2000). In general, attitude scores are close to the mean of the nine-point scales, and there is reasonable variability in the data. On the specific attitude scales, French consumers are more environmentally conscious and accord higher importance to food quality. Americans are more open to new technology, and the British are most open to new foods.[10]

Table 2 shows trust in different sources of information. It is noteworthy that Americans in all locations have more trust in government and industry and less trust in activist groups than their European counterparts.

Perceived knowledge was measured with the question "How knowledgeable would you say you are about the facts and issues concerning genetic modification in food production?" (1 = *not at all knowledgeable*, 9 = *extremely knowledgeable*). Scores averaged 3.04 for the United States and rose to 4.64 for France (i.e., consumers in all countries perceived that they had limited knowledge of GM food). Level of education was defined in terms of whether the respondent had a university degree (0 = *non-degree holder*, 1 = *degree holder*)—about equal numbers fell into each category, but the proportion with a degree was unexpectedly much higher in Reading than Grenoble.

Regression Results

Risk-benefit perception scales were used as dependent variables in a series of single equation regressions esti-

10. This could be a consequence of their traditional foods!

mated by OLS for which the independent variables were attitudes, perceived knowledge, level of education, trust in sources of information, and regional dummy variables. We specifically investigate further the questions:

- Do the specific risk/benefit categories discussed above have different antecedents?
- If so, does this provide further evidence of a "correct" level of aggregation?
- Can individuals' risk-benefit perceptions be explained by the antecedents discussed alone, or does location have a remaining independent (unexplained) impact?

Table 3 shows results for the different categories of risk-benefit perceptions (the combined business risk-benefit scale is not used, as earlier evidence suggested that that this scale did not fit the data well). The most significant attitude variable is attitude to technology—people with a generally favorable attitude to new technology also have a favorable attitude to GM technology. In particular, a favorable attitude to new technology is associated with a lower level of perceived developing-world risks. Coefficients on the other attitude variables are smaller and not always consistent with expectations (e.g., environmental attitudes are unrelated to perceived risks of GM to the environment, although this may again be associated with the problems of the New Environment Paradigm scale). All attitude variables are highly significantly associated with moral concerns. Trust variables are significant and have the expected signs. Level of education is only significant with respect to moral concerns, the negative sign indicating that more highly educated people dismiss ethical arguments against GM food production. Perceived knowledge is consistently insignificant. Much, but not all, of the locational differences are explained by the independent variables, except with respect to environmental risk perceptions.[11]

Table 4 shows results for all risks aggregated and all benefits aggregated. Technology is again the most important attitude variable, particularly with respect to perceived benefits. A lack of trust in government and the food industry is particularly strongly associated with a high level of perceived risks. Level of education is positively associated with a perception that GM technology will bring benefits. Regional differences are slightly more significant than in Table 3, particularly with respect to benefit perceptions, but most of the differences are associated with Grenoble and Lubbock.

Table 4. Results of regression analysis with two risk/benefit categories.

	All risks	All benefits
Constant	7.022***	3.941***
New environmental paradigm	.126**	-.086*
Food neophobia	-.039	-.094**
Food quality	.098**	-.107**
Technology	-.207***	.277***
Trust in government & industry information	-.329***	.246***
Trust in activist groups information	.142***	-.109**
Perceived knowledge	-.069	.059
Level of education (0 = non-degree holder; 1 = degree holder)	-.009	.115**
Region dummy 1 (Lubbock)	-.204***	.276***
Region dummy 2 (Long Beach)	-.096*	.159***
Region dummy 3 (Jacksonville)	-.134**	.119**
Region dummy 4 (Reading)	-.156***	.226***
R^2	0.386***	0.380***
Significance test on region dummies (Grenoble omitted)	**Intercepts difference (F1)**	**Slope difference (F2)**
All risks	$F1_{4,332} = 3.28$**	$F2_{32,300} = 0.81$
All benefits	$F1_{4,332} = 6.11$***	$F2_{32,300} = 1.57$**

*Note. *** significant at 0.01 level. ** significant at 0.05 level. * significant at 0.10 level.*

Conclusion

Surveys conducted in the United States, UK, and France indicate that people's risk and benefit perceptions are not unidimensional; rather, they should be represented by a number of different dimensions, although the data are not conclusive as to whether these are best represented as three scales (in which risks and benefits are viewed as distinct and moral concerns form a third dimension) or as four scales (in which different types of risks and benefits are perceived separately, as are moral concerns, but risks and benefits within each category are perceived unidimensionally). Both ways of looking at the data shed some light on the importance of different aspects of risks and benefits and the way they are related

11. Perhaps this is a result of the New Environment Paradigm scale not performing well as a measure of environmental concern (see earlier discussion) and being insignificant in explaining risk-benefit perceptions.

to more general attitudes, trust in source of information, and level of education—both important to the industry and to policy makers as well as academics.

One interesting finding from aggregating all risks and benefits together is that in none of the five locations studied did people perceive GM foods to be as risky as generally portrayed. In all locations, the majority see GM in food production as having a medium level of risk and, apart from Grenoble, this grouping represents around two thirds of those surveyed (Table 1). Perceived self and family risks and perceived environmental risks are the most important risks perceived across the locations. The single attitude variable that best explains GM risk and benefit perceptions is individuals' general attitude to new technology; Americans' generally more favorable attitude to technology partially explains their greater acceptance of GM. Trust in information provided by government and industry is likewise a very important determinant of risk and benefit perceptions; once more, the Americans' greater trust in these institutions is associated with greater acceptance of GM production. By contrast, Europeans are more trusting of consumer and environmental groups; this trust is associated with higher perceived risks and lower perceived benefits. High levels of education are associated with a greater perception of GM benefits and less moral concern about the technology. Nevertheless, there remain unexplained locational differences in risk-benefit perceptions, although these are only really important between Texas and France.

The findings suggest some ways by which greater acceptance of GM could be promoted, although none of these is short term or easy: greater education and promotion of a more favorable attitude to technology (probably related) and the development of greater trust in government and industry. Trust and risk communication are issues that have been recognized as important in recent years. This research supports the significance of trust building, if not contributing to the debate on the means of achieving it.

We see this paper as having contributed to the general debate about how to measure risk and benefit perceptions of GM products. We would also hope that the findings can be generalized to other products of new technologies for which consumers have to weigh up risks and benefits. Our results suggest that there may be a number of risk/benefit dimensions that merit investigation, although it is unlikely that these will be identical across technologies.

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Appendix A. Measurement Items for Risk-Benefit Perceptions and Moral Concerns

Agricultural and Food Business Risk (α = 0.69)

- Agricultural and food businesses could be exposed to great risk from genetic modification in food production.
- Genetic modification in food production will pose risks for agricultural and food businesses.

Table A1. Correlation between risk and benefit scales—nine scales.[a]

	BR	BB	ER	EB	FR	FB	DR	DB	MC
Business risk (BR)	1	-.313	.444	-.481	.509	-.470	.570	-.441	0.475
Business benefit (BB)		1	-.130	.342	-.265	.434	-.244	.411	-0.423
Environmental risk (ER)			1	-.520	.587	-.467	.600	-.508	0.461
Environmental benefit (EB)				1	-.562	.697	-.530	.577	-0.510
Self and family risk (FR)					1	-.612	.696	-.484	0.537
Self and family benefit (FB)						1	-.579	.639	-0.628
Developing world risk (DR)							1	-.535	0.523
Developing world benefit (DB)								1	-0.553
Moral concerns (MC)									1

[a] *Items organized in categories shown in Appendix A.*

Agricultural and Food Business Benefit (α = 0.61)

- Agricultural and food businesses could receive great benefits from genetic modification in food production.
- Genetic modification in food production will not provide benefits for agricultural and food businesses (reversed score).

Risk to Self and Family (α = 0.78)

- Genetic modification in food production will not pose risks to my family and me (reversed score).
- My family and I could be exposed to great risks from genetic modification in food production.
- I am concerned about the lack of knowledge of long-term effects of genetic modification in food production on human health.
- The side-effects from eating food produced using genetic modification are largely unknown.
- There is little danger that genetic modification in food production will result in new diseases for humans (reversed score).

Benefit to Self and Family (α = 0.77)

- The use of genetic modification in food production will not be beneficial to my family and me (reversed score).
- My family and I could benefit from genetic modification in food production.
- Genetic modification is necessary to improve the quality of food products.
- Food obtained through genetic modification will be of low quality (reversed score).
- Genetic modification will improve the quality of food products.

Table A2. Correlation between risk and benefit scales—five scales.

	BRB	ERB	FRB	DRB	MC
Composite business risk/ benefit (BRB)	1	.493	.576	.576	.554
Composite environmental risk/benefit (ERB)		1	.737	.701	.556
Composite self and family risk/benefit (FRB)			1	.725	.649
Composite developing world risk/benefit (DRB)				1	.606
Moral concerns (MC)					1

Table A3. Correlation between risk and benefit scales—three scales.

	R	B	MC
All risks (R)	1	-.694	.609
All benefits (B)			-.668
Moral concerns (MC)			1

Developing World Risk (α = 0.68)

- The developing world could be exposed to great risk from genetic modification in food production.
- Genetic modification in food production will not pose risks for the developing world (reversed score).

Developing World Benefit (α = 0.78)

- The developing world could receive great benefits from genetic modification in food production.
- Genetic modification in food production will provide no benefits to the developing world (reversed score).
- Thanks to genetic modification in food production enough food will be produced to feed the world's growing population.

Table A4. Alpha value—nine scales.

	a
Business risk	0.69
Business benefit	0.61
Environmental risk	0.67
Environmental benefit	0.65
Self and family risk	0.78
Self and family benefit	0.77
Developing world risk	0.68
Developing world benefit	0.78
Moral concerns	0.78

Table A5. Alpha value—five scales.

	a
Composite business risk/benefit	0.64
Composite environmental risk/benefit	0.75
Composite self and family risk/benefit	0.86
Composite developing world risk/benefit	0.81
Moral concerns	0.78

Table A6. Alpha value—six scales.

	a
All risks	0.88
All benefits	0.88
Moral concerns	0.78

- Genetically modifying food is the only way to increase global food production.
- The world's food supply will not be increased through the use of genetic modification (reversed score).

Environmental Risk (α = 0.67)

- Genetic modification in food production will not pose risks for the environment (reversed score).
- The environment could be exposed to great risks from genetic modification in food production.

Environmental Benefit (α = 0.65)

- The environment will not benefit from genetic modification in food production (reversed score).
- Genetic modification in food production could provide benefits for the environment.

Moral Concerns (α = 0.78)

- Man has no right to "play God" with nature.
- Genetic modification in food production is morally wrong.
- Genetic modification in food production threatens

Table A7. Alpha value—two scales.

	a
Aggregated risks/benefits	0.92
Moral concerns	0.78

Table A8. CFA overall model fit of various risk/benefit scale aggregations.

	RMSEA[a]	GFI[b]	AGFI[c]
Two scales[d]	0.11	0.74	0.70
Three scales[e]	0.09	0.80	0.76
Five scales[f]	0.10	0.75	0.70

[a] RMSEA was calculated as the square root of the mean of the squared differences between the implied and observed covariance matrices.
[b] GFI was calculated as the sum of the squared differences between the implied and observed covariance matrices.
[c] AGFI was calculated by adjusting the GFI for the degree of freedom in the model.
[d] Aggregated risks/benefits and moral concerns.
[e] All risks, all benefits, and moral concerns.
[f] Composite business risk/benefit, composite self and family risk/benefit, composite environmental risk/benefit, composite developing world risk/benefit, and moral concerns.

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