CONSUMERS' EVALUATION OF BIOTECHNOLOGY IN FOOD PRODUCTS:

NEW EVIDENCE FROM A META-SURVEY

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Abstract

Other than previous meta-analyses, we ignore the reported main outcome of a study. Instead, we focus on studies that present descriptive statistics of survey statements as long as these address consumers' evaluation of biotechnology in food products and capture responses on a numerical scale (e.g. Likert). To make these scales comparable across studies, a set of judges performed a randomized and repeated re-scaling of reported scale endpoints to a common benchmark scale. This approach allows to combine information from 1673 survey questions out of 214 different studies, covering 58 different countries and responses from more than 200 000 respondents. Findings from our mixed effects meta-model show that survey questions with positive (negative) connotations about biotechnology tend to be associated with positive (negative) measures of evaluation. After controlling for this, the European Union and many of its individual member countries appear insignificant. Evaluation of biotechnology is largely insensitive to the type of food product. Stated benefits of biotechnologies in food do not produce any significant positive reaction, except medical features build into food. Instead, price discounts, increased production and various perceived risks generate significant negative coefficients. Joint research projects between academic departments and industry consortia report more positive measures of consumer evaluation than any other type of publication.

Keywords: Biotechnology, GMO, Genes, consumers, evaluation, attitude, meta-analysis

1 Introduction

Numerous papers in economics, psychology and related social sciences have provided attempts to measure consumers' evaluation of biotechnologically modified food products. Such products may contain gene modifications, enzyme modifications, cloning and hormone treatment. By 'evaluation' we refer to studies that have aimed to provide quantitative measures of concepts such as 'acceptance' or 'perceptions', 'attitudes', and alike. Typically, during such studies, survey respondents are asked to express their preferences regarding a certain type of biotechnologically modified food product, and in a second step statistical analysis is commonly applied to condense survey information and to test hypotheses that were usually derived from some conceptual framework.

In the literature that attempts to measure consumers' evaluation of biotechnologically modified food products, reported outcome variables include e.g. estimated price markups, willingness to pay (WTP), factor loadings, risk premia, etc. Even though all these measures approach in a meta-sense an envelope of an underlying construct that represents a common basis of consumer preferences for (or against) biotechnology in food products, none of these measures is typically comparable to the other.

Nevertheless, by focusing on subsets of comparable outcome measures that such studies report, several Meta-Analyses have tried to synthesize the empirical evidence related to these underlying preference that consumers reveal with respect to biotechnologies in food products: DANNENBERG (2009) includes 59 studies, HALL, MORAN AND ALLCROFT (2006) include 22 studies; LUSK, JAMAL, KURLANDER, ROUCAN and TAULMAN (2005) include 25 studies.

However, if the literature to be meta-analyzed appears very heterogeneous according to the units of measurement by which findings are reported, as in the case of consumer evaluation of biotechnology in food products, any meta-analysis that is driven by the need to include only homogeneous outcome variables may suffer from a small and potentially biased literature sample, unless one would falsely try to compare “apples with oranges” (WACHTER 1988).

In this article we therefore argue that previous Meta-Analyses related to biotechnologies in food products have been unable to span a broader construct of consumer preferences and instead had to be kept rather narrowly focused on studies that happen to report the same or a similar outcome measure (such as WTP). Contrary to previous systematic reviews does the Meta-Analysis that we present in this article not focus on a comparison of the reported outcome measures of studies within our literature sample. Instead, we focus on studies that present descriptive statistics of survey statements, as long as these statements can be interpreted as addressing ‘consumers’ evaluation of biotechnology in food products’. Such descriptive statistics usually report at least the average (mean) response that a sample of consumers has expressed on a corresponding numerical scale. Such scales include binary (yes/no) measures as well as e.g. scales with 3, 4, etc. and even more than 10 choice categories (usually “Likert-Scales”). Furthermore, to make these descriptive statistics comparable across studies, the first part of our study included an on-line survey in which a set of judges performed in a randomized and repeated way a re-scaling of reported scale endpoints to a common benchmark scale. This procedure allowed us to derive a standardized mean response that was distributed around zero (=neutral evaluation).

The approach allowed us to combine information from 1673 survey questions that were reported by a sample of 214 different studies, covering 58 different geographical regions, such that the information in our meta-survey is based on responses from more than 200 000 respondents. Based on the assumption that all survey questions in our dataset captured a common aspect of an underlying psychological factor ‘product evaluation’, our objective was to identify how differences in the rescaled mean response rate (=our empirical representation of “evaluation”) could be explained by food product characteristics and the related biotechnologies in question, but also by informational context provided during a survey. We furthermore try to identify if and to what extent regional disparities regarding consumer attitudes towards biotechnology in food products exist, and if peer review affected reported findings within our literature.

The underlying research question of this article is therefore what type of systematic evidence the existing research shows about the way how consumers evaluate certain types of biotechnologies in different food products. This way, we intend to obtain better predictions about which group of consumers would likely be willing to accept what type of biotechnology in which food product.

Our analysis aims to serve several audiences: Scientists who work on the development of biotechnological methods in existing and future food products will hopefully get a broader and more comprehensive overview on what type of systematic evidence social sciences have so far generated with respect to the specific characteristics that a certain biotechnology would have to show before being accepted or rather dismissed by a certain group of consumers. Policymakers and decision-makers in the Agro-food business may utilize our results as background information during decisions about the potential use of biotechnology in certain food products. Finally, researchers in the social sciences will find the literature sample underlying this Meta-Analysis to be the largest set of scientific and grey papers on biotechnology in food products that has to date been in detail meta-analyzed.

The following section reviews the methodological approaches and findings of previous meta studies that have systematically analyzed the existing literature about consumers’ evaluation of biotechnology in food products. Section 3 introduces our methodological approach, presents descriptive statistics of the meta data set underlying this study and explains our econometric modeling approach. Section 4 explains findings from our mixed effects meta regression model and Section 5 discusses findings from our study and concludes.

2. Previous Reviews on Consumers' Evaluation of Biotechnology in Food Products

Systematic reviews of socio-economic studies on consumers' evaluation of biotechnology in food products very well exist: PIN and GUTTELING (2009) try to characterize the scientific literature about public perception of genomics as far as contained in Web of Science and Scopus. For this purpose they screen and categorize the abstracts and reference information of 451 published articles, but claim to have not been able to read further into each article due to the large number of studies; therefore, their study does not qualify as a Meta- Analysis in the strict sense. However, as one of their findings PIN and GUTTELING (2009) conclude that "… social science research is linked to public opinion and attitudes. European researchers tend to focus more on topics related to agri/plant genomics, while researchers in the United States focus more on the field's medical applications".

Table 1: Overview on three recent Meta-Analyses with similar scope on biotechnology

Title	DANNENBERG, 2009	HALL, MORAN and ALLCROFT, 2006	LUSK ET AL., 2005
Data	51 primary studies 114 GM food valuation estimates btw. 1992-2007. Mean participants/study = 511.	22 valuation studies & 56 WTP values. btw 1992-2003. Data divided in 3 sets.	25 valuation studies & 57 WTP values.
Selected explana-tory variables	Elicitation procedure, Sample characteristics, Food Products (GM animals 13%, products consumed by children 23%, other products 64%) & 23% of observations based on products w/ direct consumer benefit (taste, nutrition). Env. & agronomic benefits not included. Regional: 48% N.A., 25% EU, 13% Asia, 11% Aust/Oc, 3%Africa); voluntary (48%) vs. mandatory (52%) labelings.	Response rate; Survey year; Survey country; Description of food in survey; Participant group; Survey distribution method; Survey topic; Elicitation technique	Sample characteristics; Location 49% US, 33% EU, 9% Asia, 9% Canada & Australia; 20% students, 14% grocery shoppers, randomly recruited subjects; Method for eliciting consumers' valuation of GM food; Characteristics of food being valued
Depen-dent Var.	% Premium WTP for absence of GM ingrediences. Some studies report price discount req'd to accept GM. Valuation studies commonly use relative diff. to demonstrate diff. btw WTP for GM food & WTP for conventional food.	% Premium for GM free food % Premium for GM food with clear benefits	% Premium for non-GM food over GM food
Selected Results & Con-clusions	Elicitation methods & formats in primary studies affect valuation est. much more than sample characteristics. Aversion to GM food steeply increasing in Europe, only gently increasing in America and even decreasing in rest of world. Significantly higher aversion to GM food noted when animal genes involved, but effect is relatively small. GM food products in Europe may have chance only as a niche product, at least for time being, whereas they may rapidly spread out in other regions of the world.	On avg., respondents were WTP 24% premium to avoid GM food, but willing to buy GM food at 37% discount. On avg, WTP 9% extra for GM foods without clear benefits. Perceived risks of GM foods appear to outweigh promised benefits in minds of some consumers.	As much as 89% of variation in existing valuation estimates is explained by: sample characteristics; elicitation format; type of food. EU customer valuations for non-GM food 29% > US customers. Valuations in-person generates lower premiums for non-GM food, compared to tel. or mail. Premiums elicited in non-hypothetical context significantly < hypothetical premiums. Premiums using WTA value measure exceed WTP valuation. GM meat is least desired GM food. GM oil draws least concern.
Future research	Question of why European consumers persist in their distrust towards this new technology remains to be answered.	Suggests considering the differences btw European nations, rather than lumping European countries together.	Explaining why consumers have a particular valuation, predicting how these valuations change, determine effect of public policies on valuations.

Source: Own presentation.

As potential reasons for this, PIN and GUTTELING (2009) suspect not only the public interest-driven spending of governmental research funding, but also the fact that the public discourse may have caused a social bias among researchers in favor the corresponding topics. PIN and GUTTELING (2009) furthermore claim that within their literature sample much more emphasis is on the accompanying risk rather than on potential benefits of GM technologies, and they conclude that the GMO related social science publications suffer in general from inconsistent terminology, sparse use of commonly established theoretical frameworks, and overall poor quality of the abstracts in question. For instance, the authors claim that roughly 1/3 of the studies that they screen fail to mention a methodological framework at all.

The three existing Meta-Analyses which are closest to the topic of this article provide much more in-depth comparison of the studies that they meta-analyze than PIN and GUTTELING (2009) do. Table 1 summarizes these Meta-Analyses; however, the table shows that rather small literature samples were analyzed. This can be explained by the fact that only few published articles in this research area happen to provide comparable outcome measures.

Further related meta studies not reflected in Table 1 include HARTL (2007) and RODRIGUEZ and ABBOTT (2007). HARTL (2007) aims to conduct a Meta-analysis in order to identify determinants of willingness to pay (WTP) for genetically modified food. This study has been published as a thesis and reaches to similar conclusions as DANNENBERG (2009).

The work by RODRIGUEZ and ABBOTT (2007) does not appear to be a statistical meta study in the same manner as those summarized in Table 1, but highlights the importance of context (developed vs. developing world) for the way how biotechnology issues are discussed by a broad public audience. RODRIGUEZ and ABBOTT (2007) note that (studies from) developed countries would often discuss biotechnology with a focus on "food safety", whereas developing countries may be more concerned with the need for "food security". Similarly, DANNENBERG (2009) calls future research to address this observed gap, also with respect to consumer responses observed in Africa versus South America.

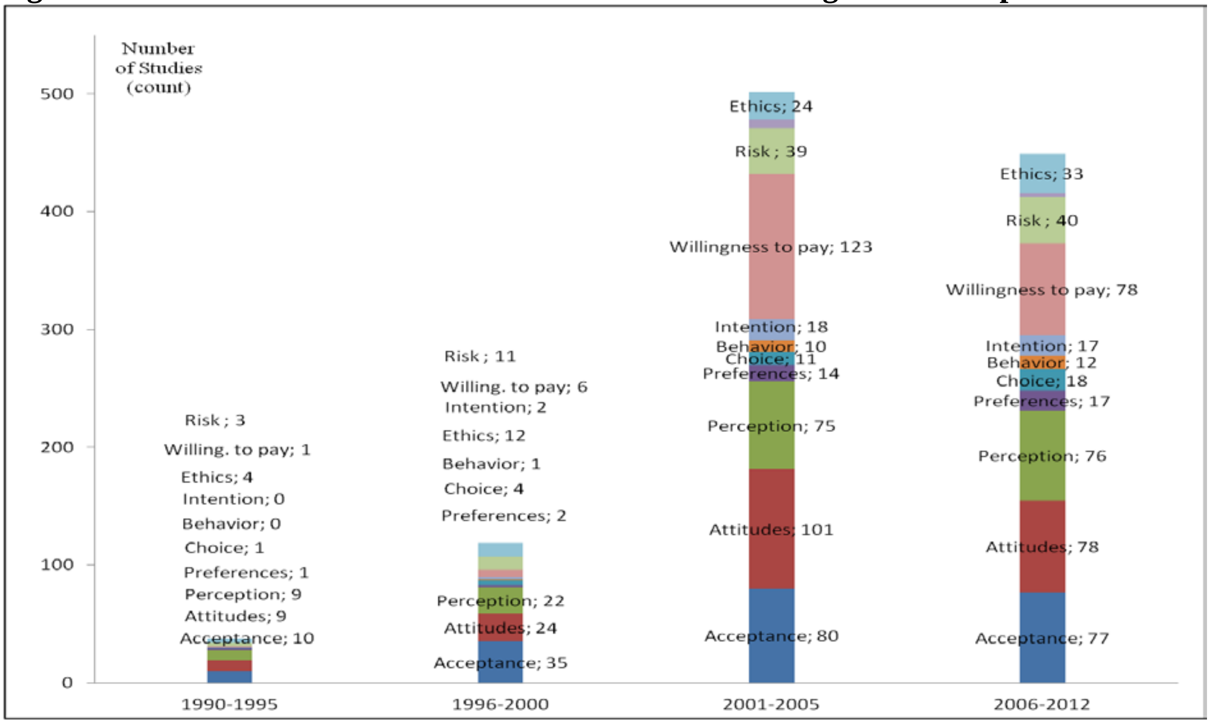
3 Data and Methodology

3.1 The literature sample

Developing a representative literature sample of the socioeconomic literature on consumers' evaluation of biotechnology in food products requires a systematic search in several literature databases such as the Web of Science and Scopus. Working paper databases have also been included in our search. The databases that were covered by our literature search include the database of the American Economic Association, EconLit, EconPapers, AgEcon Search, Agricola, the ISC Web of Knowledge, Emerald, SpringerLink, ScienceDirect, Scopus (Elsevier), Business Source Premier, Sage Premier, JSTOR, Social Sciences Citation Index, ASSIA, the online archives of Science, Nature, Scirus, Ingenta Connect, ICABR and Google Scholar.

Predefined lists of search word combinations that reflect the underlying topic "evaluation of biotechnology in food products" have been applied to each of these databases. After elimination of duplicates and removal of apparently unrelated works, a total number of about 1200 articles have been retrieved and were initially screened through a procedure similar to the one outlined in PIN and GUTTELING (2009). During this initial screening procedure the topic of each paper has been classified into different categories of topics according to the information provided in title and abstract. This information is presented in Figure 1. However, it turned out that in many cases the unit of measurement of the actual numerical findings does not coincide with these main topics, e.g. a study that appears to be about risk perception may report findings in terms of Willingness to Pay. It furthermore turned out that about 40% use qualitative approaches while 60% are empirical in nature, out of which a smaller subset uses original survey data. Furthermore, except from studies that report WTP measures, the reported numerical outcome variables differ even within the remaining categories to such an extent that hardly literature samples of more than 10 to 20 comparable publications emerge.

Figure 1: Result of the literature search after initial screening for main topic



Source: Own.

Similar to the findings by PIN and GUTTELING (2009), we conclude from this step of our analysis that only a minor share of all studies fulfills the criteria of being *i)* similar enough to each other and *ii)* thoroughly enough documented that they qualify for inclusion into a joint meta-analysis. In other words: No Meta-Analysis that selects one of the outcome categories presented in Figure 1 can claim to represent a major share of the entire existing literature with respect to consumers' evaluation of biotechnology in food products.

However, incorporating all studies that are summarized in Figure 1 within the same meta-analysis is not feasible either. The following section explains the procedure that we have applied to this literature sample in order to obtain comparable numerical information. From 680 quantitative studies initially included, 214 studies could be included into our final meta data set; a list of these studies is available in appendix A1.

3.2 The dependent variable

The dependent variable of our meta-analysis follows a fundamentally different approach than the Meta-Analyses summarized in Table 1 were using: Our approach completely ignores typical outcome variables of the studies within the literature sample summarized in Figure 1. Instead, the dependent variable of our Meta-Analysis consists of the descriptive statistics that studies report about respondents' answers to questions in the corresponding surveys. Such survey questions are typically based on different scales (i.e. binary or Likert) in order to obtain numerical assessments of the underlying psychological constructs.

However, these scales again vary widely across and sometimes within studies. Therefore, these responses had to be rescaled to a common benchmark Likert scale[1] which has been set to the following range: {-3,-2,-1,0,+1,+2,+3}. The rescaling procedure requires to express the

[1] We are grateful to Klaus Grunert and Joachim Scholderer for suggesting this approach.

maximum and minimum (=the scale ends or endpoints) of an actual scale in terms of this reference scale. This yields re-scaled endpoints in terms of the benchmark scale; with these rescaled endpoints it is possible to re-express the observed mean response $\bar{y}$ from question *r* in study *i* as a new mean $\tilde{y}_{r,i}$ through the following commonly used transformation:

$$\tilde{y}_{r,i} = \frac{\left(\bar{y}_{r,i} - \breve{x}_{r,i}\right)\left(\overline{\omega}_{r,i} - \overline{\alpha}_{r,i}\right)}{\left(x_{r,i}^{max} - x_{r,i}^{min}\right)} + \overline{\alpha}_{r,i} + \tfrac{1}{2}\left(\overline{\omega}_{r,i} - \overline{\alpha}_{r,i}\right). \quad (1)$$

In this context, x^{min}, x^{max} and $\breve{x}$ (subscripts dropped) refer, respectively, to the originally observed lower endpoint, upper endpoint and midpoint of the scale used on question *r* in study *i*. The variables $\overline{\alpha}, \overline{\omega}$ are defined as the corresponding rescaled lower endpoint and higher endpoint values. These values have been obtained during a procedure for which several research assistants had been particularly trained. These assistants have determined independently from each other their subjective assessment of the re-scaled values. For this purpose have all original statements been pooled and presented to each judge three times in randomized order using an on-line questionnaire format after which the overall means of three ratings ($\overline{\alpha}, \overline{\omega}$) and corresponding standard deviation were obtained. Care was taken to observe consistency using a set of regularly repeated hold-out statements. Table 2 illustrates the input ("Original") and output ("Rescaled") of this procedure. Alternatively, one could have performed separate Meta-Analyses on samples of studies that all use the same type of Likert scale. Detailed information about the rescaling procedure can be found by following the link in Appendix A-3.

Table 2: The rescaling procedure by example

Study	Original				Rescaled			
	Question	Scale	Anchors	Mean $\bar{y}$	Category	Min $\overline{\alpha}$	Max $\overline{\omega}$	Mean $\tilde{y}$
MOON ET AL. (2003)	"Agrobiotechnology poses hazards on eco-systems".	7 point Likert	Disagree completely… Agree completely	3.61	Consider Dangerous	-2.73	2.47	-0.47
AERNI (2005)	"how do you assess the potential of genetic engineering for solving Agr. Policy problems?"	5 point Likert	1= 'no potential at all' 5= 'very high potential'	2.20	Consider Beneficial	-2.40	2.43	-0.95
NAYGA ET AL. (2006)	"Attitude toward GM labeling"	Binary	GM products should be labeled … should not be labeled	0.07	Label Needed	-1.50	1.97	-1.28
SCHOLDERER (2005)	"Applying gene technology in food production is unnatural".	7 point Likert	strongly disagree... strongly agree	5.44	Unnatural	-2.43	2.10	0.92

Source: Own.

3.3 Explanatory Variables

In Table 2, the column "Rescaled Category" reports examples of categories that have been formed after the meta dataset had been compiled: All original survey questions have been assigned to broader categories that intend to capture the underlying meaning of the question. The labels of these categories have been determined jointly by the members of the research group based on the perceived content of a certain question. We test the statistical relationship of these categories with the dependent variable by including them as explanatory variables into our econometric meta model. Further variables included in the vector **X** of explanatory variables are explained in detail Table A-1 in the appendix A2. This table provides a full list of all explanatory variables, their included categories and the units of measurement that we have established. Most of the variables are discrete and enter the meta regression as dummy variables unless perfect multicollinearity would preclude this.

3.4 Within- and between study variability and econometric Meta Model

From an econometric perspective, the information within the meta dataset is nested in various levels: The literature sample contains *n*=214 studies, and within each study a descriptive statistic about a scaled answer to at least one question is reported, which leads to $r \geq n$ original questions (in the sample underlying this analysis r = 1673). Furthermore, these questions have been used with different numerical scales such as binary, 5- point Likert, 7-point Likert, etc. such that there are $k \leq n \leq r$ different scales in use. The way how the endpoints of a scale *k* are defined matters, because this often frames an implicit underlying suggestion for the question, as the following example illustrates: Two otherwise identical scales may show the following endpoints "Do not agree at all" / "fully agree" versus "I am rather against" / "I am definitely in favor". We suggest that such differences may have a relevant effect on the way how respondents express their evaluation, and this effect may have not been fully captures by the Meta-Analyses summarized in Table 1.

In our literature sample, there are significantly more different endpoints (*m=1,…,M*) than original scales, but not as many as individual questions, since common endpoints such as "agree/disagree" etc. occur in several studies such that $k \leq n \leq m \leq r$. Furthermore, previous Meta-Analyses have highlighted the importance of the country (*j=1,…,J*) where a study has been conducted, and potentially the year (*t=1,…,T*) when a sample was taken. Both the time and location dimension may capture different states of consumer preferences due to otherwise unobserved factors, e.g. income changes, food scandals or other shifts in the public discourse about food.

Thus, the r = 1673 observation in our dataset are expected to exhibit variation according to each of these levels. The residuals from an Ordinary Least Square (OLS) meta regression would therefore potentially be correlated with some or all of these levels, which poses a severe violation of the underlying assumptions of the OLS model. The econometric approach that we employ therefore explains the rescaled mean response value $\tilde{y}$ (equation 2) as a function of a vector **X** of explanatory factors (fixed effects). Furthermore, we investigate the variability of this dependent variable with respect to several random effects[2]. The meta model is estimated using Restricted Maximum Likelihood (REML) and follows the general framework of a "mixed effects" model (PINHEIRO and BATES 2000): Random effects are specified such that they capture potential variation due to the experimental setup of every study, due to differences between the individual survey questions, and due to potential measurement error from the rescaling procedure, while fixed effects represent coefficients that are determined across all observations. Equation 2 presents the mixed effects meta model that we estimate in matrix notation (BATES, MÄCHLER and BOLKER, 2012):

$$\tilde{\mathbf{y}} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}\mathbf{b} + \boldsymbol{\varepsilon} \tag{2}$$

In this equation, $b \sim N(0,\Psi)$ and $\varepsilon \sim N(0,\sigma^2\Lambda)$, with b being the vector of random-effect coefficients to be determined for the random effects groups contained in **Z**; **ε** is the vector of residual errors for individual observations. Ψ is the covariance matrix of the random effects, **X** is the vector of sample-generic explanatory variables and β the corresponding vector of coefficients to be estimated on **X** ("fixed effects"). This model is estimated using the lme4 package (BATES, MÄCHLER and BOLKER, 2012; BATES, 2013) from the R network software (R DEVELOPMENT CORE TEAM 2013). Model specification and selection of the final meta regression model is based on the following steps:

[2] The terminology of "fixed" versus "random" effects differs slightly between their use in relation to mixed-effects models versus econometric panel models, compare e.g. WOOLDRIGE 2001.

1. Starting out with an OLS regression, variance inflation factors (VIF) are computed in order to identify and remove those explanatory variables that are most highly collinear to other ones; VIFs up to the critical level of 10 are tolerated.

2. A mixed effects model is specified that includes the remaining explanatory variables regardless their level of significance. Alternative specifications of nested random effects for various levels are explored; selection of the best random effects specification takes place based on AIC and likelihood ratio test model selection criteria.

3. The general Model: Insignificant explanatory variables (= "fixed effects") are removed according to the lowest t-values first. This procedure is stopped as no major improvement in AIC and coefficient of determination (R^2) occurs. However, this leads to a final meta model that still includes several insignificant fixed effects coefficients (see appendix A-2).

4. The parsimonious Model: In a final step all insignificant fixed effects coefficients are removed from the general model in a stepwise procedure, dropping always the coefficient with the lowest t-value first, until no more insignificant variables remain. This leads to a restrictive and more parsimonious final meta model; however, this model does not show directly which coefficients have no significant effect on our measure of evaluation of biotechnology in food.

4 Results

According to the model selection criteria it turns out that three random effects with intercept (no varying random coefficients) perform best: random effect for the study *i*, random effect for the different scale ends *k* in use, and a random effect for the original question *r*. The standard deviation for these random effects shows that variability within the dependent variable is highest due to scale ends in use, second-highest due to the actual question that was asked and to a lesser extent due to other differences between studies (Table 3).

Table 3 presents the parsimonious final meta model as a result of step 4 of the model fitting process. The stepwise procedure of removal of insignificant fixed effects has been executed on the first model specification in Table A-2 in the appendix A2. After that, again dummies for countries and publication type have been added, which turns only two coefficients insignificant. This confirms the robustness of our meta-model because the set of significant fixed effects and the overall explanatory power of the model remain stable even under alternative specifications of **X**. The estimated coefficients of the fixed effects in Table 3 show the partial effect of a certain explanatory category on the rescaled mean response of respondents on the 7-point reference scale (midpoint=0).

Given the robustness of our econometric findings from the different model specifications presented in Table 3 and appendix A2 table A-2, several conclusions can be drawn about consumers' evaluation of biotechnology in food products:

i) Survey questions with positive connotations about biotechnology tend to be associated with positive measures of evaluation, while negative connotations seem to induce negative reactions. Many of our pre-established categories of survey questions appear significant in a way that questions which transport a positive connotation about biotechnology tend to be associated with positive measures of $\tilde{y}$, while negative suggestions implied in the question tend to induce a negative reaction, everything else equal (note that the rescaled measures have been further transformed according to their sign so that positive coefficients always reflect a positive attitude towards biotechnology and vice versa).

ii) Evaluation of biotechnology is largely insensitive to the type of food product. Expressed attitude towards and evaluation of biotechnology in food products is according to our measure largely insensitive with respect to the type of food product that respondents had to react to. Exception are, as Table A-2 in the appendix A2 shows, food products that also contain medical features, and so are biotechnologies that are presented in a very general or incomplete way (Table 3). However, this positive attitude can easily be turned into a strong negative reaction if respondents are asked to express their attitude about biotechnologies that directly modify genes of animals. These findings highlight how sensitive consumer reactions seem to be with respect to very fine positive or negative connotations that a survey question may contain. The significance of these coefficients may support the suspicion of PIN and GUTTELING (2009), that this body of socio-economic research might not be independent from the political context within which it takes place.

Table 3: The parsimonious mixed effects meta regression model

Random Effects		**Var.**	**Std.Dev.**		**Fixed contnd.**	**Coef.**	**Std.**	**t-val.**	
Original Question	(Intercept)	0.150	0.387		Austria	-0.467	0.262	-1.782	
Scale Ends	(Intercept)	0.234	0.484		Brazil	0.692	0.580	1.193	
Study ID	(Intercept)	0.072	0.268		Canada	0.857	0.260	3.291	*
Residual		0.184	0.429		Costa Rica	0.371	0.405	0.918	
					Croatia	-1.027	0.603	-1.703	
Fixed Effects	**Coef.**	**Std.**	**t-val.**		Denmark	-0.281	0.106	-2.648	*
(Intercept)	0.119	0.130	0.918		France	0.060	0.131	0.461	
Categorized Question									
Approve	0.240	0.085	2.805	*	Ghana	-0.572	0.430	-1.328	
Consider Beneficial	0.259	0.051	5.070	*	Greece	-0.471	0.326	-1.444	
Don't Value	-0.827	0.402	2.054	*	Hungary	-0.822	0.602	-1.365	
Label Properties♣	-0.743	0.325	2.289	*	India	0.502	0.221	2.274	*
Label is Needed♣	-0.457	0.100	-4.580	*	Ireland	-0.257	0.231	-1.115	
say that Not Beneficial	-0.488	0.233	2.091	*	Italy	-0.030	0.085	-0.350	
Support	0.422	0.107	3.925	*	Japan	-0.414	0.162	-2.552	*
consider unnatural	-0.358	0.145	2.476	*	Kenya	0.566	0.583	0.971	
Would Accept	0.184	0.093	1.991	*	Malaysia	0.559	0.260	2.150	*
Statement Classific.: Small Organism	-0.258	0.092	-2.803	*	Netherlands	0.643	0.252	2.550	*
Degree of Processing: InfoIncomplete	-0.155	0.047	-3.282	*	Norway	-0.406	0.137	-2.970	*
Type of GMProduct: GM in Animal	-0.150	0.071	-2.098	*	China	0.498	0.153	3.243	*
CodedTechnology:"InfoIncomplete"	0.152	0.048	3.199	*	Portugal	0.247	0.468	0.528	
CodedTechnology: "Vertical transfer"	0.505	0.208	2.425	*	Romania	-0.637	0.247	-2.583	*
Benefit: Increase Food Production	-0.337	0.149	-2.264	*	Serbia	-0.281	0.620	-0.454	
Benefit: Price reduction	-0.210	0.107	-1.965	*	South Africa	0.295	0.260	1.133	
Benefit: Extended Shelf Life	-0.445	0.135	-3.309	*	South Korea	-0.261	0.175	-1.488	
Consumer Risk HealthDisadvantage	-0.564	0.131	-4.304	*	Spain	0.570	0.237	2.400	*
Consumer Risk HigherPrice of GM	-1.189	0.365	-3.255	*	Sweden	-0.151	0.631	-0.240	
Consumer Risk no info	-0.365	0.110	-3.313	*	Switzerland	-0.289	0.395	-0.732	
Data Collection Method "WebSurvey"	-0.177	0.110	-1.601		Uganda	1.310	0.327	4.006	*
LiteratureType Bookchapters	-0.187	0.227	-0.825		USA	0.212	0.067	3.166	*
LiteratureType Conferencepaper	-0.083	0.173	-0.482		EU1991	0.352	0.469	0.751	
LiteratureType Dissertation	-0.024	0.205	-0.119		EU1993	0.797	0.425	1.876	
LiteratureType Governmental reports	0.149	0.214	0.699		EU2010	-0.421	0.445	-0.946	
LiteratureType Synthesised report	0.254	0.120	2.107	*	EU2011	-1.031	0.858	-1.203	
Literature Type Workingpaper	-0.294	0.174	-1.693		Country no inf.	1.283	0.603	2.127	*
AIC: 4125	logLik: -1995	REML dev.: 3989	R^2: 0.88						

Note: R^2 has been calculated as the squared Pearson rank correlation between actual ($\tilde{y}$) and fitted ($\hat{\tilde{y}}$) values of the model. ♣ Supporters of labeling are showing negative attitude. * Significant at 5% or better.

iii) Gene modifications and transfers that stay within the same species (vertical) are generally more appreciated than all other technologies, while not informing consumers about this is also significant (Table 3) .

iv) Stated benefits of biotechnologies in food do not produce any significant positive reaction. Instead, price discounts, extended shelf life or increased production quantities due to genetic modifications generate significant negative coefficients on our meta-measure. Several negative coefficients indicate that price discounts or extended shelf life are features of GMOs that consumers on average do not seem to appreciate. The strongest negative effect on attitude however occurs for a genetically modified food product that is more expensive than its conventional counterpart. Thus, biotechnologies in food products so far seem to be recognized by consumers as inferior goods relative to related food products without the use of such technologies.

v) Instead, the evaluation of biotechnology seems to be driven by the perception of certain risks related to the technology in question.

vi) Surveys that do not include information about potential technological risks at all generate significantly negative findings of evaluation, while missing information about the potential benefits of a certain biotechnology appears insignificant (and therefore do not appear in Table 3 but in appendix A2, Table A-2).

vii) Web surveys generate substantially more negative evaluations of biotechnology than all other data generating techniques.

viii) Country dummies add only limited explanatory power to the model (this cannot be seen from Table 3 but is obvious from R^2 values of the models in Table A-2 in the appendix). Table 3 shows that especially the European Union and many of its individual member countries appear insignificant, while Spain and the Netherlands (Denmark, Romania) exhibit positive (negative) and significant coefficients. This finding is in stark contrast to the findings of previous Meta-Analyses (Table 1). However, the suspicion of PIN amd GUTTELING (2009), that GMO related research in Europe would be influenced by the overall political discourse on this topic suggests an explanation for our empirical finding: our analysis controls through random and fixed effects more narrowly than previous Meta-Analyses for the specific underlying intonation that a question may carry (see finding *i* and *ii*). Therefore, previous meta studies may have identified an “anti-biotechnology attitude” of European consumers since they did not fully control for these issues. However, this European effect could potentially have been ‘built into’ certain surveys through the specific connotation of certain questions or scale ends. However, our results also show that other OECD countries such as Japan, Switzerland and Norway indeed reveal significant negative evaluation, while several developing countries as well as the USA and Canada show significant positive evaluation of biotechnology in food products.

*ix) Reports about joint research projects between academic departments and industry consortia report more positive measures of consumer evaluation than any other type of publication.*Testing for the potential effect of peer review reveals no significantly different evaluation reported in grey literature relative to peer-reviewed journal articles, which may indicate that peer review does not systematically influence the results. However, a significant positive evaluation is found for synthesized reports, such as they are typically generated out of joint projects between academic departments and the biotechnology- or food industry.

5. Discussion and Conclusion

On the assumption that all survey questions in our dataset captured a common aspect of an underlying psychological factor ‘product evaluation’, our objective was to identify how differences in the rescaled mean response rate (=our empirical representation of ‘evaluation’) could be explained by food product characteristics and the related biotechnologies in question, but also by informational context provided during a survey. Our findings are in this respect in line with the results from previous Meta-Analyses: the way how consumers are interviewed about their attitude and evaluation of various biotechnologies in food products largely determines their answer. However, while previous Meta-Analyses rather shed light on methodological differences between studies, the present analysis has put emphasis on the specific positive or negative connotation of each single question (modeled as random effects), and the degree to which additional information about the type of food product and the type of technology has been provided. The large contribution of this random effect to the overall explanatory power of the model indicates that seemingly small differences in the wording of a specific survey question in combination with the label of the endpoints of related numerical scales on which respondents express their opinion can induce potentially important differences in the type of answers.

We have furthermore tried to identify if and to what extent regional disparities regarding consumer attitudes towards biotechnology in food products exist. Surprisingly, the present study does not confirm earlier findings about a general aversion of European consumers against biotechnology in food products. While most EU aggregates remain insignificant, the breakdown into EU member countries reveals that especially in the largest countries no significantly different effect from the average country included in the literature sample can be determined. In addition, the small number of significantly negative country effects within the EU is met by an equal number of significant positive effects from other EU member countries. We therefore conclude that after controlling for the specific type how a survey question has been asked and how the endpoints of the corresponding answering scales have been framed, no substantial evidence could be found to sustain the claim that European consumers in general would be more reluctant to accept biotechnology in food products than the sample average. We interpret this finding similar to PIN and GUTTELING (2009), who suggest that social science research always remains tied to its socioeconomic context or, in other words, we suspect that the public discourse and the strong opinion expressed by some European policymakers over the past years against biotechnology has led more researchers in Europe than in other regions to ask survey questions that bear a biotechnology-critical tendency. However, the significant positive effects that we find for other counties such as the USA clearly shows that an independent country effect very well seems to exist.

The underlying research question of this article has been to determine from a representative sample of the socioeconomic literature on consumers' evaluation of biotechnology in food products which group of consumers would likely accept what type of biotechnology in which food product. In this respect do our findings support the view that humans tend to be more afraid of uncertain risks and hazards than being optimistic about uncertain future benefits. While some proponents of biotechnology in food products frequently claim that the benefits of specific technologies have only insufficiently been communicated to consumers, our results indicate that working on convincing and transparent risk control mechanisms is a more promising way to win public support for a certain biotechnology. Alternatively, scientists could focus on the development of food products that appear more easily controllable (e.g. enzymes that stay in laboratories) rather than technologies that many consumers would perceive as drastically "against Nature" (e.g. animal genes into plants).

In addition, out of all potential benefits that have been assessed by the literature in our sample, it turns out that conventional advantages such as price or taste improvements are not appreciated; food products with medical features added through biotechnologies appeared instead to be the most promising direction for future research and engineering.

In closing we emphasize that our results would potentially be even more precise and more useful for microbiologists, food scientists and other researchers outside the social sciences if the studies included in our literature sample would have been conducted according to a common standard regarding the information that has to be reported about empirical research in this area, and if a common set of terminology would have been adopted. Finally, our finding that collaborations of academic departments with industry trusts seem to generate significantly higher evaluation outcomes than all other publication types should give rise to concerns.

We conclude that even though social science researchers have actively addressed consumers' evaluation of biotechnology in food products through a large volume of published papers, responsible stakeholders in professional organizations, editorial boards and funding institutions could perhaps in future make this research even more efficient and beneficial for society by aligning it to a comprehensive, joint and interdisciplinary research strategy.

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Appendix

A1: The literature sample used for the estimation of the meta regression model (equation 2): https://docs.google.com/file/d/0BzyG4seDILXsalEwUm5OUjQybHM/edit?usp=sharing

A2: Description of all explanatory variable categories and additional meta regression results: https://docs.google.com/file/d/0BzyG4seDILXsUkcta0tYeDBTZlk/edit?usp=sharing

A3: Detailed rater instructions for the rescaling experiment: https://docs.google.com/file/d/0BzyG4seDILXsRFRudkZaTjZTR2c/edit?usp=sharing