Discussion Paper No. 08-096

Is it Who You Ask or How You Ask? Findings of a Meta-Analysis on Genetically Modified Food Valuation Studies

Astrid Dannenberg

ZEW
Zentrum für Europäische Wirtschaftsforschung GmbH
Centre for European Economic Research

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Non-technical summary

The introduction of genetically modified (GM) content in food products has been the object of controversial debates in several countries for more than a decade. Opponents warn against potential dangers to the environment and human health which arise from growing and consuming GM crops. Proponents believe that the current approval process for the commercialisation of GM foods is sound and that GM crops can have positive environmental, health and social impacts. Given these conflicting lines of argumentation, politicians face the challenge of how to regulate the GM food market. Numerous GM food valuation studies have been conducted in order to elicit consumer preferences for GM food and help politicians to efficiently regulate the market. These studies, however, present a wide range of valuation estimates and, due to differences with respect to estimation procedures, sample characteristics, products, and regional focus, a direct comparison of results and an explanation of what determines study-to-study differences becomes challenging. Against this background, the aim of this paper is to identify the determinants of the variation in GM food valuation studies. For this purpose, a meta-analysis of 46 primary studies reporting a total of 108 valuation estimates for GM food is conducted. Given the large variety of estimation procedures across studies, meta-analysis is a good opportunity to test for methodological differences. The results show that elicitation methods and formats used in the primary studies affect valuation estimates to a much larger extent than do sample characteristics. Moreover, consumer aversion to GM food seems to have increased over time. Previous findings that consumer valuation strongly depends on the type of food product and varies among regions are confirmed.

Das Wichtigste in Kürze

Die Einführung von genetisch modifizierten (GM) Lebensmitteln wird seit über einem Jahrzehnt sehr kontrovers diskutiert. Gegner warnen vor den Schäden, die durch den Anbau und den Konsum von GM-Lebensmitteln für die Umwelt und die Gesundheit entstehen könnten und betonen das Fehlen von Langzeitstudien zur Untersuchung solcher Risiken. Befürworter dagegen argumentieren, dass der Genehmigungsprozess für die kommerzielle Nutzung von GM-Produkten zuverlässig sei und dass die Nutzung der Gentechnik positive Wirkungen für Umwelt und Gesundheit habe und zu einer höheren landwirtschaftlichen Produktivität führe. Angesichts dieses deutlichen Widerspruchs steht die Politik vor der Aufgabe, den Markt für GM-Lebensmittel zu regulieren. Mittlerweile wurden zahlreiche Studien durchgeführt, um die Präferenzen der Konsumenten bezüglich GM-Lebensmittel zu ermitteln und eine Hilfestellung für die effiziente Regulierung des Marktes zu bieten. Diese Studien liefern jedoch sehr unterschiedliche Schätzungen für die Konsumentenpräferenzen. Aufgrund der Unterschiede im Hinblick auf Erhebungsmethode, Stichprobencharakteristika, zu bewertende Produkte und Ort der Datenerhebung ist es nicht möglich, die Ergebnisse der Studien direkt zu vergleichen und die unterschiedlichen Ergebnisse zu erklären. Vor diesem Hintergrund ist das Ziel der vorliegenden Arbeit, die Determinanten der Variation in den ermittelten Konsumentenpräferenzen zu bestimmen. Dafür wird eine Meta-Analyse erstellt mit 46 Primärstudien, die insgesamt 108 Beobachtungen für GM-Lebensmittelbewertungen liefern. Die Resultate zeigen, dass die Erhebungsmethoden einen weitaus größeren Einfluss auf die Ergebnisse haben als die Stichprobencharakteristika. Es deutet sich außerdem an, dass die Aversion gegen GM-Lebensmittel über die Zeit zugenommen hat. Bisherige Befunde, dass die ermittelten Präferenzen stark vom zu bewertenden Produkt abhängen und zwischen Regionen variieren, werden bestätigt.

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Astrid Dannenberg

Centre for European Economic Research (ZEW)

L 7, 1 68161 Mannheim, Germany

November 2008

Abstract: This paper presents a meta-analysis of 46 primary studies reporting a total of 108 genetically modified food valuation estimates. The analysis shows that elicitation methods and formats used in the primary studies affect valuation estimates much more than do sample characteristics. Moreover, consumer aversion to genetically modified food seems to have increased over time. Previous findings are confirmed that consumer valuation strongly depends on the type of food product and varies among regions.

JEL classification: Q18, Q51, Q55
Keywords: meta-analysis, consumer preferences, genetically modified food
Acknowledgement: The author thanks Diana Heger, Ulrich Oberndorfer, Bodo Sturm and Andreas Ziegler for helpful comments and Jessica Oettel for assistance with the data collection.

1. Introduction

The introduction of genetically modified (GM) content in food products has been the object of highly controversial debates in several countries for over a decade. Opponents, such as Greenpeace International, warn against potential dangers to the environment and human health that arise from growing and consuming GM crop (Greenpeace International 2008). They emphasise possible but not yet identified health risks, such as allergic reactions, and environmental risks, such as pest resistance and loss of biodiversity, and denounce the absence of long-term studies investigating these risks. On the other hand, proponents, such as the Council for Biotechnology Information, believe that the approval process in place for the commercialisation of GM foods is sound and that GM crops can have positive environmental impacts due to reduced pesticide and herbicide use, positive social impacts due to an increase in farmland productivity and positive health impacts, since they reduce farmers' exposure to toxic substances, especially in developing countries (Council for Biotechnology Information 2008).

Given the distribution of conflicting information and the resulting uncertainty among consumers, politicians face the pressing problem of how to regulate the GM food market. There are three main options (Noussair et al. 2008): (i) banning GM foods, (ii) allowing GM foods without segregation from their conventional counterparts and (iii) allowing GM foods with segregation from their conventional counterparts. The first two policies have serious potential drawbacks. Banning GM products may be inefficient since potential welfare gains from the use of biotechnology would thus not be realised. On the other hand, allowing the introduction of GM foods into the food chain without segregation reduces consumer choice and, given consumers' strong resistance, may cause the collapse of entire market segments. The third option implies the creation of two separate production tracks and the introduction of a labelling scheme allowing consumers to choose between GM and non-GM food products. While segregation and labelling of GM products is beyond dispute, the choice of the labelling scheme, mandatory or voluntary, is a highly controversial issue. Some countries, such as the United States and Canada, have opted for a voluntary labelling scheme arguing that the market will offer the appropriate labelling incentives and produce an optimal degree of segregation among products without the unnecessary costs a mandatory scheme would imply. Other countries, such as the European Union member states, Australia, New Zealand and Japan have opted for a mandatory labelling scheme arguing that consumers have the right to know.

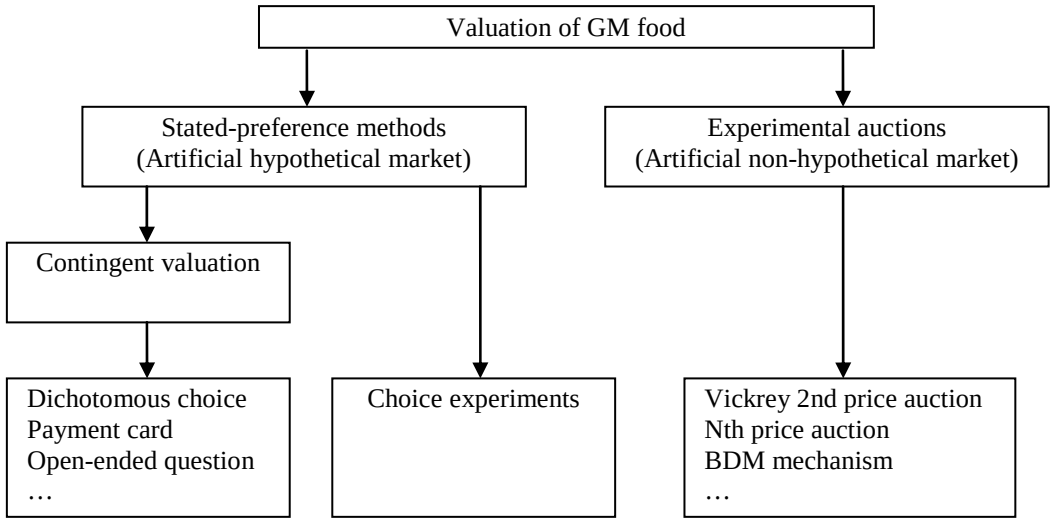
In order to elicit consumer preferences for GM food and help politicians to efficiently regulate the market, numerous GM food valuation studies have been conducted., These studies, however, present a wide range of valuation estimates and, due to differences with respect to elicitation procedures, sample characteristics, products, and regional focus, a direct comparison of results and an explanation of what determines the large study-to-study variation in valuation estimates becomes challenging. Against this background, the aim of this paper is to identify the determinants of the variation in GM food valuation studies. For this purpose, we conduct a meta-analysis of 46 studies which report a total of 108 valuation estimates for GM food.

The paper is structured as follows. Section 2 gives a short review of the relevant literature. Section 3 describes the data derived from the primary studies. Section 4 presents the results of the meta-regression model. Section 5 analyses the robustness of the results and presents several sensitivity tests. Section 6 summarises the findings and concludes.

2. Background

While under a mandatory labelling scheme all GM products must be labelled as such, under a voluntary labelling scheme producers may voluntarily place labels on their products. In the latter case, producers typically use labels to mark non-GM products. In most countries with a mandatory labelling scheme, GM-labelled products are virtually nonexistent. In countries with a voluntary labelling scheme, GM products are available but they are unlabelled and therefore indistinguishable from their conventional counterparts. In both situations researchers wanting to investigate consumer preferences for GM products cannot rely on data derived from the food market ("revealed preferences"). For this reason they have to turn to data derived from artificial and hypothetical markets created by "stated-preference" surveys, which are widely used in the field of environmental goods valuation. Stated-preference methods involve the elicitation of responses to open-ended questions or predefined alternatives in the form of ratings, rankings or choices (Bateman et al. 2002). Prominent examples include contingent valuation methods, such as dichotomous choice or payment card, and choice experiments. Since food products, unlike most environmental goods, are mobile goods, researchers may also use experimental methods, namely experimental auctions, in order to elicit consumer valuation. Experimental auctions involve real purchase, thus creating artificial but non-hypothetical markets. There are several auction mechanisms such as the Vickrey *2*nd price auction, the random *n*th price auction, or the Becker-deGroot-Marschak mechanism (Shogren 2005). Figure 1 summarises the elicitation methods that are used in GM food valuation studies. The variety of elicitation methods in GM food valuation studies is a good (and rare) opportunity to test for methodological differences by means of a meta-analysis.

Figure 1: Elicitation methods for GM food valuation



A qualitative review of the literature on consumer preferences for GM food helps identifying the following stylised facts. Firstly, consumers normally value non-GM foods higher than GM foods. The presence of GM ingredients is valued higher only if it is linked to certain benefits, e.g. increased shelf life or better taste (e.g. Noussair et al. 2002, Loureiro and Bugbee 2005). Secondly, consumer valuation strongly varies with country or region (Lusk et al. 2003, 2004). Thirdly, consumer valuation varies with product and type of genetic modification. For example, the aversion to GM foods is higher if animal genes are involved (e.g. James and Burton 2003, Kaneko 2005). Finally, attitudinal variables, such as concerns for health and environment, generally seem to be more important for the valuation of GM foods than

socioeconomic variables, such as gender or age (e.g. Chen and Chern 2002, Kimenju and De Groote 2008).

Lusk et al. (2005) conducted a meta-analysis of 25 primary studies that report a total of 57 valuations for GM food. These primary studies involve several stated-preference methods as well as experimental auctions. Their findings allow, for the first time, the creation of stylised facts that are not conditional on the results of one or few particular studies. The results indicate that the variation in existing value estimates can for the most part be explained by the sample characteristics, the elicitation method, and the type of food. Concretely, the results show that the price premium consumers are willing to pay for non-GM food is (a) significantly higher for European consumers than for consumers from the United States, (b) significantly lower for shoppers than for the general population, (c) significantly higher when values are elicited in-person, i.e. via interview or experiment, (d) significantly lower when values are elicited in a non-hypothetical context than in a hypothetical setting, (e) significantly higher when values are estimated as willingness-to-accept (WTA) compared to WTP, (f) significantly higher when GM meat products are valued, and (g) significantly lower when the GM foods valued provide benefits to consumers.

Our analysis offers an update of this study. It includes approximately twice as many primary studies and valuation estimates. The results confirm in part the effects of region and consumer benefits but differ with respect to the effects of elicitation formats and sample characteristics. Furthermore, since our study includes a larger number of observations we are able to analyse the effects of different elicitation methods, which is important for all researchers who use these methods.

3. Data

The analysis includes 46 primary studies which report a total of 108 valuation estimates for GM food. The extensive search for appropriate studies has incorporated all economic databases and methods of internet research commonly used. The analysis includes only studies which report a valuation estimate for GM food relative to the non-GM counterpart or vice versa. Furthermore, in cases where multiple papers used the same data set, only one paper has been taken into account. After the selection process our primary study data set comprised 29 journal papers, 10 working papers and research reports, 5 papers presented at meetings or conferences, and 2 dissertations. The main features and results of the studies are presented in Table 7 in the appendix. Data collection in all primary studies took place between 1992 and 2007. The mean number of participants per study is 514, the median is 271. Here we do not count all participants in a survey or experiment but only those who gave valid responses which could be used for the data evaluation of the respective study. Seventy-one percent of the 108 observations have been elicited from a random sample[1], 18 % from grocery shoppers[2], and 11 % from students. Forty-one percent of observations have been estimated via choice experiment, 25 % via experimental auction, 21 % via dichotomous choice, 11 % via payment card, and 2% via open-ended question. All auctions but only 4 % of the other (stated-preference) observations involved real purchase, i.e. a non-hypothetical decision situation for participants. Considering the format, 49 % of observations have been elicited in-person, i.e. via interview or experiment, 34 % by mail, 14 % via telephone, and 3 % online. Twenty-three percent of observations are based on valuations of GM products that provide a

[1] In the strict sense, most of these samples are not random themselves, more precisely, they are drawn from a random sampling.

[2] Since individuals from a random sample and students are in principle also shoppers, the real difference is that these studies were conducted in or in front of supermarkets. For convenience, we will nevertheless call the participants in these studies shoppers.

direct benefit to consumers. Direct benefits means that consumers profit directly from buying or consuming the product, for instance due to better taste or nutrition value ("second generation" GM foods). Environmental benefits, such as pesticide reduction, or agronomic benefits ("first generation" GM foods) have not been included as consumer benefits. Concerning the region, most observations (47 %) have been collected in (North-) America, 27 % in Europe, 14 % in Asia, 9 % in Australia/Oceania, and 3 % in Africa. Almost half of the observations (49 %) come from countries with a voluntary labelling scheme for GM foods and the other half (51 %) from countries with a mandatory labelling scheme. In order to classify the food products used in the primary studies we apply the classification of Lusk et al. (2005). Thus, observations are divided into 36 % processed goods (bread, cereals, potato crisps, cookies, muffins, chocolate bars, biscuits, noodles, meal, sauce, beer, tofu, natto), 29 % products made from GM animals or GM-fed animals (meat, fish, eggs, butter, milk, cheese), 20 % fresh goods (fresh fruit, vegetable, rice, or unspecified), and 15 % vegetable oil. In summary, the primary studies differ with respect to several features which can serve as potential explanatory variables in the meta-regression. At the same time these differences are likely to pose the problem of sample data heterogeneity, which we will address among other problems in the sensitivity analysis in section 5.

The percentage price premium consumers are willing to pay for the absence of GM ingredients is the dependent variable of the meta-regression. Some primary studies, however, do not report the price premium but rather the price discount consumers require in order to accept GM ingredients, without giving details of the absolute prices or values. In these cases, we use the link between premium (p) and discount (d), $p = 1/(1-d) - 1$, in order to calculate the premium. When primary studies do not directly report premiums or discounts, the premium for non-GM is calculated as $(v_{non-GM} - v_{GM})/v_{GM}$ and the discount for GM is calculated as $(v_{non-GM} - v_{GM})/v_{non-GM}$ where v_{GM} is the value or price for the GM product and v_{non-GM} is the value or price for the non-GM version of the product.[3] Table 1 shows the summary statistics of the percentage premium for non-GM food.

Table 1: Summary statistics of the dependent variable

Obs.	Mean	Std. Dev.	Median	Min	Max
108	46%	94.93	18%	-40%	784%

Note: values rounded

Negative values indicate that the GM product is preferred to the non-GM version. A premium of zero percent indicates indifference between both versions. The divergence between mean and median suggests that it is a right-skewed distribution, i.e. there are some (positive) outliers. In particular, the maximum amount of 784 % is an extreme outlier being more than twice as large as the second highest value of 376 %.

Table 2 presents the definition and summary statistics of the explanatory variables which will be used in the regression model in the next section. All variables are dummy variables taking the value one or zero. As the variable *auction* virtually coincides with non-hypothetical valuation tasks, the regression model will not include a further regressor for whether the valuation task was hypothetical or non-hypothetical. All the same, there is some overlapping in the explanatory variables which may pose the problem of multicollinearity. For example, all auctions were conducted in-person and all samples comprising grocery shoppers were

[3] Details of the procedures used to calculate or estimate each value are available from the author upon request.

asked in-person. The sensitivity analysis in section 5 will present some regressions estimated on the basis of selected subsamples with less overlap in the explanatory variables.

Table 2: Summary statistics and definitions of explanatory variables

Variable	Definition	Mean	Weighted mean
Random sample	1 if sample comprised random sample; 0 if otherwise	0.71 0.45	0.77 (0.42)
Shopper	1 if sample comprised grocery shoppers; 0 if otherwise	0.18 (0.38)	0.16 (0.37)
Student	1 if sample comprised students*; 0 if otherwise	0.11 (0.32)	0.06 (0.25)
Choice experiment	1 if value elicited via choice experiment; 0 if otherwise	0.41 (0.49)	0.47 (0.50)
Dichotomous	1 of value elicited via dichotomous choice; 0 if otherwise	0.21 (0.41)	0.24 (0.43)
Auction	1 if value elicited via auction; 0 if otherwise	0.25 (0.44)	0.13 (0.33)
Other-method	1 if value elicited via payment card or open-ended question; 0 if otherwise	0.13 (0.34)	0.18 (0.39)
In-person	1 if value elicited in-person (interview or experiment); 0 if otherwise	0.49 (0.50)	0.34 (0.47)
Mail	1 if value elicited by mail; 0 if otherwise	0.34 (0.48)	0.42 (0.50)
Other-format	1 if value elicited via telephone or online; 0 if otherwise	0.17 (0.37)	0.25 (0.43)
Benefit	1 if GM product had direct benefit to consumers; 0 if otherwise	0.23 (0.42)	0.27 (0.44)
America	1 if respondents from (North-)America; 0 if otherwise	0.47 (0.50)	0.48 (0.50)
Europe	1 if respondents from Europe; 0 if otherwise	0.27 (0.45)	0.25 (0.43)
Asia	1 if respondents from Asia; 0 if otherwise	0.14 (0.35)	0.15 (0.36)
Other-countries	1 if respondents from Africa or Australia/Oceania; 0 if otherwise	0.12 (0.33)	0.12 (0.33)
Animal	1 if product was made from GM animal or GM-fed animal; 0 if otherwise	0.29 (0.04)	0.30 (0.04)

Notes: Numbers in parentheses are standard deviations. Number of observations is 108. The third column presents mean values weighted by root sample size.
*One primary sample comprised university members which is pooled with the student samples.

4. Results

Due to different primary sample sizes, different sample observations and different estimation procedures, the GM valuation estimates are likely to have non-homogeneous variances (heteroskedasticity). Estimates with smaller variances are generally more reliable and should therefore have more weight in the regression (Nelson and Kennedy, 2008). For this reason we will present results of linear regression models estimated by ordinary least squares (OLS) as well as weighted least squares (WLS). As we do not know all primary valuation variances we proxy the variances using the primary study sample size and employ a WLS model, where valuations are weighted by the root sample size as proposed by Nelson and Kennedy.

Table 3 presents the results of the OLS and WLS regressions. The last two columns show the results of regressions that exclude the outlier value of 784 %. In addition to the explanatory variables described in table 2, the regressions include dummy variables for the year of

primary data collection in order to test whether GM food valuation has changed over time. The baseline is the oldest primary study which was conducted in 1992.

Table 3: Results of linear regression models – total sample

	Coefficients Model 1		Coefficients Model 2	
Variable	Unweighted	Weighted	Unweighted	Weighted
Constant	-48.111	-38.715	-14.656	-15.327
	(100.486)	(101.347)	(51.458)	(66.423)
1998	-44.198	-84.178	-65.838	-98.100
	(126.176)	(124.758)	(64.573)	(81.734)
1999	-34.356	-18.405	-19.562	-17.363
	(100.315)	(103.555)	(51.335)	(67.834)
2000	11.417	10.504	-0.545	-7.370
	(99.669)	(101.938)	(51.002)	(66.796)
2001	19.288	29.135	16.271	22.463
	(94.937)	(97.504)	(48.545)	(63.874)
2002	29.519	6.208	-3.740	-14.963
	(93.817)	(97.209)	(48.049)	(63.708)
2003	70.024	67.796	55.446	51.670
	(96.503)	(99.627)	(49.385)	(65.278)
2004	5.621	-1.912	-8.038	-16.085
	(107.936)	(104.818)	(55.232)	(68.678)
2005	28.066	27.143	19.026	12.950
	(112.461)	(107.150)	(57.544)	(70.201)
2007	-22.422	-11.474	22.513	20.717
	(99.738)	(104.107)	(51.112)	(68.261)
Shopper	-50.278	-0.195	11.214	39.710
	(49.912)	(50.083)	(25.840)	(33.017)
Student	-38.007	-25.748	-0.090	4.176
	(37.669)	(39.997)	(19.426)	(26.348)
Dichotomous	-5.880	-28.279	-15.340	-30.957**
	(28.950)	(21.031)	(14.825)	(13.779)
Auction	17.168	20.498	3.658	9.988
	(38.925)	(41.149)	(19.935)	(26.973)
Other-method	-36.360	-45.056**	-42.087***	-45.742***
	(30.131)	(20.452)	(15.421)	(13.397)
In-person	62.209	44.762	17.442	10.319
	(48.787)	(46.980)	(25.126)	(30.941)
Mail	60.575**	69.557***	55.402***	69.027***
	(27.846)	(18.632)	(14.251)	(12.205)
Benefit	-22.966	-32.944*	-36.901***	-40.543***
	(25.249)	(19.510)	(12.949)	(12.780)
Europe	119.516***	115.026***	90.136***	100.858***
	(24.001)	(18.674)	(12.424)	(12.304)
Asia	36.273	32.350	23.817*	25.984*
	(27.922)	(21.512)	(14.309)	(14.104)
Other-countries	-33.563	-37.805	-32.537*	-37.496**
	(33.790)	(25.976)	(17.289)	(17.016)
Animal	14.708	17.147	15.548	16.386
	(28.785)	(20.398)	(14.728)	(13.362)
No. of observations	108	108	107	107
F-Statistic	2.92***	4.64***	7.48***	9.39***
R^2	0.416	0.531	0.649	0.699
Adj R^2	0.274	0.417	0.562	0.624

Notes: Asterisks (*, **, ***) denote statistical significance at the 0.1, 0.05 and 0.01 levels, respectively. In all regressions the White's general test statistic is not significant ($p > 0.1$). Numbers in parentheses are conventional standard errors. As opposed to model 1, model 2 excludes the outlier value.

In particular the WLS regression which excludes the outlier is capable of explaining a considerable amount of the valuation variation, which is why we choose this model for interpretation. In this model the variables *dichotomous*, *other-method*, *mail*, *benefit*, *europe*, *asia*, and *other-countries* are at least weakly significant. Results indicate that Europeans are willing to pay premiums for non-GM food that are over 100 percentage points higher than the ones (North-) American consumers are willing to pay. Considering the product valued, results show that the premium for non-GM food is over 40 percentage points lower when the product entails a direct benefit to consumers. These findings are already well known and similar to the results of Lusk et al. (2005).

The analysis also reveals some new and to a certain extent surprising insights particularly with respect to the design and sample characteristics of the primary studies. First of all, we cannot reject the hypothesis that grocery shoppers, students, and individuals drawn from random samples value GM food equally. Hence, sample characteristics do not seem to be important for the valuation of GM food. By contrast, elicitation method and format play an important role. Other things being equal, the estimated premium for non-GM food is approximately 70 percentage points higher if respondents answer by mail compared to values collected via telephone or online. Valuations elicited by means of the dichotomous choice technique are 31 percentage points lower than those elicited via choice experiment. Valuations collected via payment card or open-ended question are 46 percentage points lower. There is no significant difference between experimental auctions and choice experiments. Thus, we do not find evidence for the presence of a hypothetical bias.

Furthermore, while the positive coefficient of the variable *asia* suggests that Asian consumers, too, have a higher aversion to GM food than American consumers, the aversion to GM food in other countries, namely Australia/Oceania and Africa, seems to be lower. The coefficients of the time dummies indicate that the aversion to GM food tends to increase over time, although the dummy variables are insignificant. The sensitivity analysis in the next section will show whether these results are stable.

5. Sensitivity analysis

Assessing 130 meta-studies in the field of environmental and resource economics, Nelson and Kennedy (2008) identify, besides heteroskedasticity, non-independence of multiple observations from primary studies and sample data heterogeneity as the main problems in meta-analysis. Non-independence of multiple observations from primary studies gives rise to within-study autocorrelation, i.e. correlated errors among certain groups of estimates. Correlated effect-size estimates imply biased standard error estimates. Nelson and Kennedy strongly recommend adjusting for non-independence by using a single estimate per primary study, panel-data methods or other econometric methods for dealing with correlated data. Sample data heterogeneity refers to effect-size estimates from primary studies that do not all estimate the same effect, which is the case for most economic studies. There are two basic causes of heterogeneity, factual and methodological causes. Factual heterogeneity exists when there are real differences between valuation estimates, for example, due to different regions. Methodological heterogeneity arises from the use of different primary study designs and methods. The most common way to handle heterogeneity is to include explanatory variables, typically binary dummies, representing all observed sources of the estimate variation, as has been done in the regressions presented in the previous section. In addition, Nelson and Kennedy recommend that meta-regressions be also estimated on the basis of more homogeneous subsamples.

Table 4: Results of WLS regressions – selected subsamples

Variable	Selected subsamples		
	One observation per study	All stated-preference methods	Choice experiments
Constant	13.531	-125.447**	-26.989
	(77.702)	(61.173)	(85.643)
1998	-103.222	baseline	baseline
	(83.057)		
1999	-51.992	107.660	dropped
	(79.482)	(70.437)	
2000	-32.802	99.314	-12.249
	(76.888)	(61.330)	(86.781)
2001	-11.565	142.827**	37.572
	(72.292)	(61.987)	(85.997)
2002	-50.294	88.944	8.977
	(70.954)	(59.024)	(77.152)
2003	33.032	159.254***	81.593
	(74.121)	(59.740)	(84.168)
2004	-59.476	90.453	-10.815
	(84.414)	(64.380)	(90.358)
2005	-18.829	120.199*	dropped
	(87.989)	(68.650)	
2007	-31.946	dropped	dropped
	(80.220)		
Shopper	22.097	23.828	-8.246
	(42.319)	(52.545)	(89.116)
Student	-9.582	-37.226	31.541
	(36.472)	(58.298)	(93.750)
Dichotomous	-40.176**	-36.733**	dropped
	(18.282)	(15.853)	
Auction	5.863	dropped	dropped
	(35.917)		
Other-method	-33.367	-44.082***	dropped
	(24.866)	(15.310)	
In-person	15.921	33.464	-14.430
	(42.327)	(51.920)	(74.340)
Mail	70.326***	73.702***	75.734**
	(21.409)	(14.147)	(28.202)
Benefit	-40.752**	-44.820***	-51.860
	(19.287)	(15.347)	(32.366)
Europe	105.501***	103.987***	92.783***
	(18.928)	(14.703)	(25.851)
Asia	67.554**	30.119*	-6.833
	(25.570)	(16.427)	(26.603)
Other-countries	-43.727*	-42.559**	-11.942
	(23.338)	(19.918)	(42.517)
Animal	0.019	18.014	10.728
	(34.503)	(15.007)	(23.243)
No. of observations	46	81	44
F-Statistic	4.24***	8.45***	7.09***
R^2	0.788	0.710	0.774
Adj R^2	0.602	0.626	0.665

Notes: Asterisks (*, **, ***) denote statistical significance at the 0.1, 0.05 and 0.01 levels, respectively. In all regressions the White's general test statistic is insignificant ($p > 0.1$). Numbers in parentheses are conventional standard errors.

Since we draw more than one valuation estimate from each primary study (mean observation per study is 2.35), non-independence within studies is a relevant issue for this meta-regression. Therefore, we reran the meta-regression with only one (randomly drawn)

observation per study. The results are shown in the first column of table 4. To simplify matters, the table shows only the results of the WLS regression.

Let us first consider the formerly, i.e. in table 3, statistically significant variables. The signs of the coefficients are all unchanged. In most cases, the sizes of the coefficients are also similar to those of the regression estimated on the basis of the total sample. Only one variable, namely *other-method*, is not significant anymore. The formerly insignificant variables remain insignificant. The impression of increasing aversion to GM food over time, i.e. increasing time dummies, cannot be confirmed.

Given the methodological variety of primary studies, data heterogeneity is also a relevant issue. The question arises whether the different elicitation methods used constitute the same data generating process. Therefore, the use of regression models estimated on the basis of more homogeneous subsamples, i.e. primary studies employing similar or the same elicitation method, seems to be appropriate. Sample size permitting, we reran the meta-regression for all stated-preference studies and choice experiment studies. The results of the WLS regression on all stated-preference studies are presented in the second column of table 4. Let us again first focus on the formerly statistically significant variables. All these variables remain significant and their coefficients virtually equal those of the regression estimated on the basis of the total sample. The formerly insignificant variables remain insignificant. In the regression on all stated-preference studies the year *1998* serves as data collection baseline. All studies conducted in later years produced higher estimates for GM food aversion with the differences being at least weakly significant in the years *2001*, *2003*, and *2005*.

The last column in table 4 presents the results of the WLS regression on all primary studies using choice experiments. Considering the formerly significant variables we find that except for *asia* the coefficients have the same sign as before and in most cases they are of similar size. While the variables *mail* and *europe* are still significant, the variables *benefit*, *asia*, and *other-countries* are not significant any more. The formerly insignificant variables remain insignificant. The time dummies do not exhibit a certain structure.

Another way to deal with data heterogeneity is to transform the data in a way that makes the distribution more even. One possibility is to categorise individual aversion to GM food into certain classes. Besides, this is an elegant way of avoiding the problem of primary studies giving either price discount for GM food or price premium for non-GM food. The categorisation of premiums and discounts results in a dependent variable measured on an interval scale. Table 6 in the appendix presents the classes of aversion with the corresponding intervals of premium and discount. Please note that, in contrast to ordinal data, the distances between the categories are known and, in case of the discount interval, equal which allows us to analyse the outcome with a linear regression model. Figure 2 in the appendix shows the distribution of aversion classes. The figure reveals that there are no extreme outliers. At the most, two observations in the left-most position could be considered as outliers, though not extreme ones. Table 5 presents the results of the OLS and WSL regressions using the aversion class as dependent variable. The last two columns show the results of the regressions that exclude the two outlier values.

Table 5: Results of OLS and WLS regressions – with the dependent variable measured on an interval scale

	Coefficients Model 1		Coefficients Model 2	
Variable	Unweighted	Weighted	Unweighted	Weighted
Constant	-0.095	-0.299	0.294	0.384
	(2.016)	(2.659)	(1.890)	(2.413)
1998	-0.808	-1.058	-0.319	-0.774
	(2.531)	(3.273)	(2.373)	(2.965)
1999	-0.088	0.300	-0.224	-0.011
	(2.013)	(2.717)	(1.884)	(2.461)
2000	1.114	1.133	1.410	1.302
	(2.000)	()2.674	(1.873)	(2.422)
2001	0.582	0.521	1.286	1.366
	(1.905)	(2.558)	(1.792)	(2.324)
2002	0.825	0.826	0.930	0.660
	(1.882)	(2.550)	(1.762)	(2.310)
2003	2.672	2.869	2.679	2.594
	(1.936)	(2.614)	(1.812)	(2.368)
2004	1.304	1.457	1.239	1.099
	(2.165)	(2.750)	(2.027)	(2.492)
2005	1.148	1.349	1.347	1.353
	(2.256)	(2.811)	(2.112)	(2.546)
2007	1.108	1.173	1.117	1.152
	(2.001)	(2.731)	(1.873)	(2.474)
Shopper	-1.206	-1.361	-0.437	-0.030
	(1.001)	(1.314)	(0.959)	(1.225)
Student	-0.426	-0.432	-0.188	-0.127
	(0.756)	(1.049)	(0.710)	(0.953)
Dichotomous	-0.546	-0.759	-0.671	-1.029**
	(0.581)	(0.552)	(0.545)	(0.503)
Auction	-0.179	-0.410	0.279	0.258
	(0.781)	(1.080)	(0.741)	(0.989)
Other-method	-1.168*	-1.366**	-1.480**	-1.702***
	(0.605)	(0.537)	(0.572)	(0.491)
In-person	1.841*	2.278*	0.512	0.477
	(0.979)	(1.233)	(0.982)	(1.184)
Mail	1.805***	2.093***	1.059*	1.285***
	(0.559)	(0.489)	(0.559)	(0.477)
Benefit	-3.240***	-3.417***	-2.541***	-2.650***
	(0.507)	(0.512)	(0.509)	(0.493)
Europe	3.169***	3.160***	3.306***	3.284***
	(0.482)	(0.490)	(0.452)	(0.445)
Asia	0.897	0.827	0.813	0.688
	(0.560)	(0.564)	(0.525)	(0.512)
Other-countries	-1.400**	-1.567**	-1.054	-1.120*
	(0.678)	(0.682)	(0.641)	(0.625)
Animal	1.098*	1.281**	0.644	0.659
	(0.578)	(0.535)	(0.554)	()0.503
No. of observations	108	108	106	106
F-Statistic	10.93***	11.83***	10.28***	10.86***
R^2	0.727	0.743	0.720	0.731
Adj R^2	0.661	0.680	0.650	0.664

Notes: Asterisks (*, **, ***) denote statistical significance at the 0.1, 0.05 and 0.01 levels, respectively. In all regressions the White's general test statistic is not significant ($p > 0.1$). Numbers in parentheses are conventional standard errors. As opposed to model 1, model 2 excludes the two outlier values.

Dividing the coefficients by ten gives us the effects of the explanatory variables on the price discount consumers require in order to buy GM food (see table 6 in the appendix). Comparing

the results in table 5 with the results in table 3, we can state that the signs of the coefficients of all formerly significant variables are the same. In model 1, except for the variables *dichotomous* and *asia* all formerly significant variables remain significant. Except for the variables *in-person* and *animal* all formerly insignificant variables remain insignificant. In model 2, and, in particular, in the WLS regression, the level of significance of the coefficients remains virtually the same. Except for the variable *asia* all formerly significant variables remain significant and all formerly insignificant variables remain insignificant. The time dummies *1998* and *1999* are negative and they are positive in all later years, thus supporting the finding that the aversion to GM food has increased over time.

Overall, we can state that the main findings presented in the previous section are relatively robust. The application of regression models estimated on the basis of a sample consisting of one observation per primary study or on the basis of more homogeneous subsamples as well as regression models with the dependent variable measured on an interval scale does not strongly affect the results.

6. Summary and conclusion

The aim of this paper is to identify the determinants of the large differences among valuation estimates in GM food valuation studies. For this purpose a meta-analysis of 46 studies reporting 108 valuation estimates is conducted.

The regression results show that the elicitation method and the elicitation format are far more important and influential than the sample characteristics. In simple terms, GM food valuation depends more on how you ask than who you ask. For GM food valuation, there are no significant differences between grocery shoppers, students and the general population. Considering the usual efforts researchers make in order to find the appropriate sample for their object of investigation and the long-running discussion on representative samples, this finding is somewhat surprising. By contrast, both elicitation method and format of the primary studies strongly affect the valuation estimates. The estimated percentage premium for non-GM food elicited via choice experiments is significantly higher than the premium elicited via dichotomous choice and other stated-preference methods, i.e. open-ended questions or payment card. Please note that this does not mean that the valuation estimates elicited via choice experiments are less reliable. On the contrary, it is possible that other methods induce more protest (zero) bids and therefore deliver lower estimates for the mean premium. The valuation estimates collected in experimental auctions are not significantly different from the values elicited via choice experiments. This means that there is no evidence for the presence of a hypothetical bias, which is good news for choice experiments. Unfortunately, the meta-analysis does not enable us to identify the best elicitation method for GM food valuation. Although experimental auctions have the basic advantage of creating non-hypothetical markets, the decision situation of consumers in the experiment is still artificial and it is not identical to the decision situation in the supermarket. Hence, further research is needed to compare consumer preferences collected via stated-preference and experimental methods with data derived from the food market or alternatively, as long as GM-labelled food products are non-existent, with data derived from field experiments.

Another interesting result is that the estimated aversion to GM food is significantly higher when the survey is conducted by mail. This supports previous findings from other economic scopes, for example charity behaviour, that the way of asking people may strongly affect their responses (e.g. Frey and Meier 2002). Thus, researchers wanting to analyse consumer preferences for GM food (or other non-market goods) should be aware of the sensitivity of valuation estimates regarding elicitation method and format. Since GM food is definitely an

important future market with very high stakes for the parties involved, politicians should be aware as well.

The meta-regression confirms previous findings that (a) Europeans are the most sceptical group with regard to GM food and (b) the acceptance of GM food is higher when GM products are associated with direct benefits to consumers. The scepticism of European consumers has brought about a quite hesitant GM food policy in the European Union. The analysis suggests that there are further regional differences. While Asian consumers are also more sceptical towards GM food than American consumers, consumers from other countries, namely Australia/Oceania and Africa, seem to be less concerned about GM food. The evidence for this, however, is much weaker and needs further investigations. Moreover, we have to bear in mind that there may be differences within regions that could not be considered in this analysis.

The results indicate furthermore that consumer aversion to GM food has increased over time. This development may be the consequence of several food scandals, for example the BSE crisis in Europe or the recent melamine crisis in China, as well as the effective work of some environmental groups. This finding is not as robust as the others and needs to be confirmed by future research. We still can conclude that consumers have not become accustomed to GM food and politicians are well advised to take into account the uncertainty and scepticism of consumers.

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Appendix

Table 6: Classes of Aversion to GM food

Premium interval		Discount interval		Aversion Class
(-0.41	-0.38]	(-0.70	-0.60]	-6
(-0.38	-0.33]	(-0.60	-0.50]	-5
(-0.33	-0.29]	(-0.50	-0.40]	-4
(-0.29	-0.23]	(-0.40	-0.30]	-3
(-0.23	-0.17]	(-0.30	-0.20]	-2
(-0.17	-0.09]	(-0.20	-0.10]	-1
(-0.09	0.00]	(-0.10	0.00]	0
(0.00	0.11]	(0.00	0.10]	1
(0.11	0.25]	(0.10	0.20]	2
(0.25	0.43]	(0.20	0.30]	3
(0.43	0.67]	(0.30	0.40]	4
(0.67	1.00]	(0.40	0.50]	5
(1.00	1.50]	(0.50	0.60]	6
(1.50	2.33]	(0.60	0.70]	7
(2.33	4.00]	(0.70	0.80]	8
(4.00	9.00]	(0.80	0.90]	9
(9.00		(0.90	1.00]	10

Figure 2: Relative frequency of aversion classes [in %]

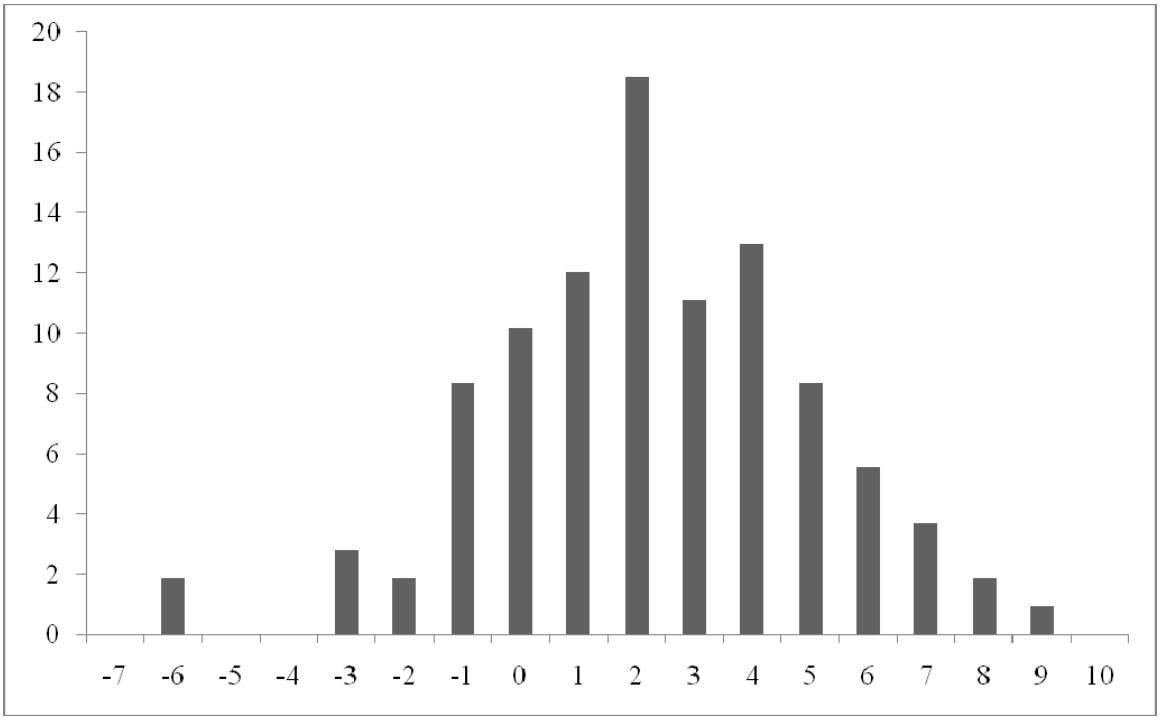

Table 7: Primary Studies

Study	Year	Sample	Method	Format	Benefit	Location	Product	Premium [%]
Baker / Burnham 2001	2000	Random	Choice experiment	Mail	No	America	Cornflakes	40
Boccaletti / Moro 2000	1999	Random	Payment card	Phone	Yes	Europe	General	-7
Bugbee / Loureiro 2003	1999	Random	Dichotomous	Mail	Yes	America	Tomato	-11
Bugbee / Loureiro 2003	1999	Random	Dichotomous	Mail	Yes	America	Beef	-17
Buhr et al. 1993	1992	Students	Auction	In-person	Yes	America	Pork sandwich	-15
Bukenya / Wright 2007	2003	Shoppers	Dichotomous	In-person	Yes	America	Tomato	20
Burton / Pearse 2002	2001	Random	Choice experiment	Mail	No	Australia	Beer	15
Burton et al. 2001	2000	Random	Choice experiment	Mail	No	Europe	General	169
Carlsson et al. 2004	2003	Random	Choice experiment	Mail	No	Europe	GM-fed chicken	285
Carlsson et al. 2004	2003	Random	Choice experiment	Mail	No	Europe	GM-fed beef	144
Carlsson et al. 2004	2003	Random	Choice experiment	Mail	No	Europe	GM-fed pork	376
Carlsson et al. 2004	2003	Random	Choice experiment	Mail	No	Europe	GM-fed egg	156
Chen / Chern 2002	2001	Random	Dichotomous	Mail	No	America	Vegetable oil	7
Chen / Chern 2002	2001	Random	Dichotomous	Mail	No	America	Breakfast cereals	15
Chen / Chern 2002	2001	Random	Dichotomous	Mail	No	America	Salmon	22
Chern / Rickertsen 2002	2001	Students	Choice experiment	In-person	No	Europe	Vegetable oil	62
Chern / Rickertsen 2002	2001	Students	Choice experiment	In-person	No	America	Vegetable oil	56
Chern / Rickertsen 2002	2001	Students	Choice experiment	In-person	No	Asia	Vegetable oil	37
Chern / Rickertsen 2002	2001	Students	Choice experiment	In-person	no	Asia	Vegetable oil	19
Chern et al. 2002	2002	Random	Choice experiment	Phone	No	Europe	Salmon	67
Chern et al. 2002	2002	Random	Choice experiment	Phone	No	Europe	GM-fed salmon	54
Chern et al. 2002	2002	Random	Choice experiment	Phone	No	America	Salmon	53
Chern et al. 2002	2002	Random	Choice experiment	Phone	No	America	GM-fed salmon	41
Dannenberg et al. 2008	2007	Random	Auction	In-person	No	Europe	Soy bean oil	89
Dannenberg et al. 2008	2007	Random	Auction	In-person	No	Europe	Chocolate bar	144
Gath / Alvensleben 1998	1998	Shoppers	Choice experiment	In-person	No	Europe	Soft cheese	54
Grimsrud et al. 2002	2002	Shoppers	Dichotomous	In-person	No	Europe	Bread	92
Grimsrud et al. 2002	2002	Shoppers	Dichotomous	In-person	No	Europe	GM-fed salmon	127
Han 2006	2005	Random	Open-ended question	Mail	Yes	America	Potato	-9
Han 2006	2005	Random	Open-ended question	Mail	Yes	America	Beef	-14
Hu 2006	2002	Random	Dichotomous	Mail	No	Asia	Vegetable oil	31
Hu 2006	2002	Random	Dichotomous	Mail	No	Asia	Vegetable oil	60
Huffman 2007	2007	Random	Auction	In-person	Yes	America	Broccoli	-12
Huffman 2007	2007	Random	Auction	In-person	Yes	America	Tomato	-2
Huffman 2007	2007	Random	Auction	In-person	Yes	America	Potato	-5
Huffman et al. 2002	2001	Random	Auction	In-person	No	America	Vegetable oil	18

Huffman et al. 2002	2001	Random	Auction	In-person	No	America	Tortilla chips	14
Huffman et al. 2002	2001	Random	Auction	In-person	No	America	Potato	14
Jaeger / Harker 2004	2003	Random	Auction	In-person	No	Oceania	Kiwi	61
James / Burton 2003	2000	Random	Choice experiment	Mail	No	Australia	General plant	10
James / Burton 2003	2000	Random	Choice experiment	Mail	No	Australia	General plant and animal	64
Kaneko 2005	2003	Random	Choice experiment	Phone	No	America	Vegetable oil	45
Kaneko 2005	2003	Random	Choice experiment	Phone	No	America	Cornflakes	36
Kaneko 2005	2003	Random	Choice experiment	Phone	No	America	GM-fed salmon	38
Kaneko 2005	2003	Random	Choice experiment	Phone	No	America	Salmon	57
Kaneko 2005	2003	Random	Choice experiment	Phone	No	Asia	Soy bean oil	46
Kaneko 2005	2003	Random	Choice experiment	Phone	No	Asia	Tofu	70
Kaneko 2005	2003	Random	Choice experiment	Phone	No	Asia	GM-fed salmon	23
Kaneko / Chern 2005	2003	Shoppers	Auction	In-person	No	Asia	Canola oil	59
Kaneko / Chern 2005	2003	University staff	Auction	In-person	No	Asia	Natto	79
Kaye-Blake et al. 2004	2003	Random	Payment card	Mail	Yes	Oceania	Butter from GM cows	0
Kaye-Blake et al. 2004	2003	Random	Payment card	Mail	No	Oceania	Milk from GM-fed cows	3
Kaye-Blake et al. 2004	2003	Random	Payment card	Mail	No	Oceania	Sheep meat	0
Kaye-Blake et al. 2004	2003	Random	Payment card	Mail	No	Oceania	Maize	3
Kaye-Blake et al. 2004	2003	Random	Payment card	Mail	No	Oceania	Bread	9
Kaye-Blake et al. 2004	2003	Random	Payment card	Mail	Yes	Oceania	Apples	-2
Kimenju / De Groote 2008	2003	Shoppers	Dichotomous	In-person	No	Africa	Maize meal	-12
Li et al. 2002	2002	Shoppers	Dichotomous	In-person	Yes	Asia	Rice	-28
Li et al. 2002	2002	Shoppers	Dichotomous	In-person	No	Asia	Soy bean oil	-14
Li et al. 2004	2003	Shoppers	Dichotomous	In-person	No	America	GM-fed beef	6
Loureiro / Bugbee 2005	2003	Random	Payment card	Mail	Yes	America	Tomato	-2
Loureiro / Hine 2002	2000	Shoppers	Payment card	In-person	No	America	Potato	6
Lusk 2003	2001	Random	Dichotomous	Mail	Yes	America	Golden rice	-25
Lusk et al. 2001	2000	Students	Auction	In-person	No	America	Corn chips	14
Lusk et al. 2002	2001	Students	Choice experiment	In-person	No	America	Corn chips	12
Lusk et al. 2002	2001	Students	Choice experiment	In-person	Yes	America	Corn chips	0
Lusk et al. 2003	2000	Random	Choice experiment	Mail	No	America	GM-fed beef	39
Lusk et al. 2003	2000	Random	Choice experiment	Mail	No	Europe	GM-fed beef	74
Lusk et al. 2003	2000	Random	Choice experiment	Mail	No	Europe	GM-fed beef	90
Lusk et al. 2003	2000	Random	Choice experiment	Mail	No	Europe	GM-fed beef	110
Lusk et al. 2004	2002	Random	Auction	In-person	No	America	Cookie	47
Lusk et al. 2004	2002	Random	Auction	In-person	No	Europe	Cookie	160
Lusk et al. 2004	2002	Random	Auction	In-person	No	Europe	Cookie	784
McCluskey / Wahl 2003	2001	Shoppers	Dichotomous	In-person	No	Asia	Noodles	150
McCluskey / Wahl 2003	2001	Shoppers	Dichotomous	In-person	No	Asia	Tofu	178

McCluskey / Wahl 2003	2002	Shoppers	Dichotomous	In-person	No	Europe	Salmon	127
McCluskey / Wahl 2003	2002	Shoppers	Dichotomous	In-person	No	Europe	Bread	100
McCluskey / Wahl 2003	2002	Shoppers	Dichotomous	In-person	No	Asia	Rice	-28
McCluskey / Wahl 2003	2002	Shoppers	Dichotomous	In-person	No	Asia	Soy bean oil	-14
Moon / Balasubramanian 2003	2000	Random	Dichotomous	Mail	No	America	Breakfast cereals	12
Moon / Balasubramanian 2003	2000	Random	Payment card	Mail	No	America	Breakfast cereals	10
Moon / Balasubramanian 2003	2002	Random	Dichotomous	Online	No	Europe	Breakfast cereals	35
Moon / Balasubramanian 2003	2002	Random	Payment card	Online	No	Europe	Breakfast cereals	19
Moon et al. 2006	2004	Random	Payment card	Online	No	Europe	Breakfast cereals	30
Noussair et al. 2002	1999	Random	Auction	In-person	No	Europe	Chocolate bar	43
Noussair et al. 2004	2000	Random	Auction	In-person	No	Europe	Biscuits	75
Onyango et al. 2006	2004	Random	Choice experiment	Mail	No	America	Cornflakes	18
Onyango et al. 2006	2004	Random	Choice experiment	Mail	Yes	America	Cornflakes	6
Rousu et al. 2002	2001	Random	Auction	In-person	No	America	Vegetable oil	16
Rousu et al. 2002	2001	Random	Auction	In-person	No	America	Tortilla chips	17
Rousu et al. 2002	2001	Random	Auction	In-person	No	America	Potato	17
Rousu et al. 2004	2001	Random	Auction	In-person	No	America	Vegetable oil	8
Rousu et al. 2004	2001	Random	Auction	In-person	No	America	Tortilla chips	14
Rousu et al. 2004	2001	Random	Auction	In-person	No	America	Potato	10
Teisl et al. 2003	2002	Random	Choice experiment	Mail	Yes	America	Bread	0
Teisl et al. 2003	2002	Random	Choice experiment	Mail	Yes	America	Eggs	0
Teisl et al. 2003	2002	Random	Choice experiment	Mail	Yes	America	Corn (frozen)	0
Tonsor et al. 2005	2002	Shoppers	Choice experiment	In-person	No	Europe	GM-fed beef	33
Tonsor et al. 2005	2002	Shoppers	Choice experiment	In-person	No	Europe	GM-fed beef	89
Tonsor et al. 2005	2002	Shoppers	Choice experiment	In-person	No	Europe	GM-fed beef	41
Vermeulen et al. 2005	2003	Random	Choice experiment	In-person	No	Africa	Maize meal	18
Vermeulen et al. 2005	2003	Random	Choice experiment	In-person	Yes	Africa	Maize meal	-13
Wachenheim / VanWechel 2004	2002	Students	Auction	In-person	No	America	Cookie	10
Wachenheim / VanWechel 2004	2002	Students	Auction	In-person	No	America	Potato chips	11
Wachenheim / VanWechel 2004	2002	Students	Auction	In-person	No	America	Muffins	14
West et al. 2002	2001	Random	Choice experiment	Phone	Yes	America	Tomato sauce	-40
West et al. 2002	2001	Random	Choice experiment	Phone	Yes	America	Potato chips	-39
West et al. 2002	2001	Random	Choice experiment	Phone	Yes	America	Chicken	-19