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Consumer choices for nano-food and nano-packaging in France and Germany

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Abstract

An experiment with different information treatments was conducted in France and Germany to evaluate consumers' willingness to pay (WTP) for food nanotechnology focusing on two applications: nano-fortification with vitamins and nano-packaging. Results show that many consumers in both countries are reluctant to accept nanotechnology in food. Being confronted with general information on nanotechnology, econometric estimations of WTP reveal that French consumers are more reluctant to accept nano-packaging, whereas German consumers are less inclined to accept nano-fortification compared with the respective other application. More detailed information on nanotechnology has a negative impact when voluntary access to relevant information is assured.

Keywords: experimental economics, food innovation, consumer information, cross-country comparison

JEL classification: C91, D83, I10

1. Introduction

In the last couple of decades, controversies around food technologies and innovations often gained considerable momentum. Dimensions of the controversy are not limited to health or environmental safety. Ethical and societal positions are often expressed by consumer groups who question the type of economic development the world should progress in. As in the case of genetically modified (GM) organisms, these discussions can lead to regulatory

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turmoil, resulting in a considerable impediment for the food industry in bringing innovation forward.

The diffusion of food and food-packaging produced by means of nanotechnology is likely to rise over the next few years, even if the consumer perception regarding this new technology is uncertain (Kuzma and VerHage, 2006). Too many reluctant consumers could jeopardise the future development of the technology. 'Nano-food' can be defined as food that has been produced or packaged by nanotechnology techniques (Joseph and Morrison, 2006). Nanoscale molecules show greater chemical reactivity or greater catalytic behaviour compared with classical molecules (Gaskell *et al.*, 2006; Renn and Roco, 2006). Nanotechnology for food-packaging aims at reducing ultraviolet UV-light exposure or microbial growth. Moreover, food safety can be improved by nano-sensors able to detect pathogens or contaminants (Weiss, Takhistov and McClemens, 2006). Through encapsulation, nanotechnology allows improvement in fortification with functional ingredients (Chen, Remondetto, Subirade, 2006; Weiss, Takhistov and McClemens, 2006).

These promising applications, however, need to be pondered in relationship with scientific studies that have pointed to possible risks related to the production of nano-materials (Arnall, 2004; Dreher, 2004; Hoet, Brüske-Hohlfeld and Salata, 2004). In particular, some nano-particles are toxic to animals and human tissues (e.g. Oberdörster, Oberdörster and Oberdörster, 2005; Wang *et al*., 2006). Moreover, it is further considered as likely that, during their production or consumption, nano-particles will be released into the environment and pose risks such as toxic effects on aquatic organisms (EFSA, 2009). Eventually, the patent system may increase market concentration accompanied by reinforcement of multinational enterprises in the food sector (ETC, 2004). All these issues may worry and muddle up consumers, while producers could be reluctant to offer these innovative products with potential benefits.

The present paper investigates French and German consumers' decisions for nanotechnology in the food domain. The purpose of this paper was to evaluate the impact of information on consumer choice when an innovation like nanotechnology is at stake and may have important but uncertain consequences on health, environment and society. We investigate the impact of information on the acceptance of and willingness to pay (WTP) for an orange juice fortified with vitamin D by means of nanotechnology (in the following called nano-food) and an orange juice for which the bottle is produced by means of nanotechnology for protecting food nutrients from damage by UV-light (in the following called nano-packaging).

We analyse the reaction to (i) very general information about the technology and to (ii) additional, more specific information on possible health, societal or environmental benefits and risks. Furthermore, we compare consumer reaction to food nanotechnology and the related risk-benefit information between France and Germany. This will be done for the two different types of application (nano-food and nano-packaging). Consumers' valuations are measured by elicitation of their hypothetical WTP and changes in WTP.

Because we could not find any existing nanotechnology food on the market, we elicited hypothetical WTP, thus avoiding confusion and deception of participants.

Our focus on WTP pursues and deepens the work by Siegrist *et al*. (2007, 2008), who focused on the general acceptance of nanotechnology in food without eliciting any WTP. In our paper, the elicitation of WTP allows us to get a detailed picture of consumer reaction with regard to food nanotechnology beyond the extremes of acceptance or rejection of nanotechnology products. Furthermore, the comparison between France and Germany may be a first step to examine whether or not consumer reaction varies across countries. The same question will be analysed regarding the impact by type of information.

We show that many consumers in both countries are reluctant to accept nanotechnology in food. This result is coming from the revelation of general information and subsequently from 'balanced' detailed messages revealing information about risks and benefits. The reluctance is particularly salient when the type of detailed information is chosen by participants among three different types of information. Econometric estimations of WTP, when being confronted with general information on nanotechnology, reveal that French consumers are more hesitant with regard to nano-packaging and German consumers are more so regarding nano-fortification compared with the respective other application. Beyond these differences, our paper shows a convergence of French and German consumer preferences and a reluctance to accept new technologies in food with successive information available.

Our paper differs from previous contributions on nanotechnologies. In particular, studies on consumers' perception of nanotechnology found that the closer products are to the human body, the higher is consumers' reluctance (Siegrist *et al*., 2007, 2008; BfR, 2008a[1]). Participants perceived nano-applications for improved food-packaging as more beneficial than nano-applications for which the nano-material was part of the food product (Siegrist *et al*., 2007). 'Nano-outside' (namely, nano-application in food packaging) and 'nano-inside' (namely, nano-application for fortifying foods with nutrients) are the two significant factors influencing respondents' acceptance (Siegrist *et al*., 2008). Our paper mitigates the extent of this difference since the participants' reluctance for nano-outside (with the bottle impeding damage due to UV light) is similar to the one for nano-inside (with orange juice fortified with vitamin D) if consumers are informed about the impact of the technology and we can show that the effect is mostly related to the initial benefit evaluation before information.

The current scientific assessment of food nanotechnology is characterised by numerous uncertainties regarding risk characteristics. In addition, previous research has shown that knowledge about nanotechnology among consumers is limited (Cobb and Macoubrie, 2004; BfR, 2008a; Kahan *et al*., 2009;

1 Medical applications of nanotechnology were not included in the study by the BfR (2008a).

Vandermoere *et al*., 2010a). Under these conditions, it has been shown that people use heuristics to process new (risk) information and to evaluate a new technology (Tversky and Kahnemann, 1974; Kahan *et al*., 2009). Furthermore, the role of initial attitudes and the perception of other food technologies have been found to be important for the perception of new, unknown food technologies (Visschers *et al*., 2007; Costa-Font, Gil and Traill, 2008 for a review; Kahan *et al*., 2009). For example, consumers' prior beliefs about GM food were found to be important for the impact of information on genetic modification (Huffman *et al*., 2007), for the evaluation of conflicting information (Costa-Font and Mossialos, 2005) and for the impact of benefit information on biotechnology, which was determined by people's prior acceptance of GM food (Lusk *et al*., 2004). Prior beliefs in terms of subjective knowledge furthermore seem to be determined by general attitudes and values (Costa-Font, Gil and Traill, 2008). This paper will acknowledge these results and include decision heuristics in the empirical analysis of consumer choices. We are able to show that a proxy on general technology attitude (using risk perception of GM food) and prior knowledge of nanotechnology can help explain the acceptance of the new technology.

In the following sections, we describe the experiment and discuss the results. The paper concludes with a discussion of the implications for public policy.

2. The experiment

This section will successively detail the sample, the choice of products, the revealed information and the experimental procedure. The experiment kept the same protocol across countries in order to allow comparison.

2.1. The sample

The experiment was conducted in Munich, Germany, in multiple sessions in January and February 2009 with a sample of 143 participants, and in Paris, France, in multiple sessions in March 2009 with a sample of 152 participants. For both countries, the samples were randomly selected based on the quota method, such that they are representative for age groups and for socio-economic status of the population of the respective city. Participants were contacted by phone and asked to participate in a one-hour experiment about food and nutritive behaviour.

Table 1 reports information on the composition of both samples along with statistics on the population of France and Germany. Women make up a share of 52 per cent of the sample in France and 55 per cent of the sample in Germany. The average age is 46 years in both countries. The average income is EUR 3,279 in the sample in Paris and EUR 2,589 in the sample in Munich.

Table 1. Descriptive statistics about the two samples and the population

	Sample France	France[a]	Sample Germany	Germany[b]
Gender (per cent)				
Female = 0	52.3	52	54.5	51
Male = 1	47.7	48	45.5	49
Age in years, mean (standard deviation)	46.40 (18.28)	39.4	45.74 (14.35)	43.8
Household's monthly net income in euros[c], mean (standard deviation)	3,278.73 (2,165.68)	2,871	2,588.77 (1,630.76)	2,914
Number of participants	152		143	

[a]National Institute of Statistics and Economic Studies, 2008.
[b]Federal Statistic Office of Germany, 2008.
[c]As income was asked in form of intervals, the interval midpoints were selected for statistical calculations.

2.2. The products

This experiment used 1-litre bottles of orange juice. As no orange juice based on nanotechnology is sold in Germany and France, we 'created' the nano-characteristics based on a review of literature leading us to select the most likely nanotechnology application in the food domain.[2] Thus, this experiment elicits hypothetical responses, since it was not feasible to give real nano-products to participants at the end of each laboratory session, if they chose nano-products during the experiment. As all elicited WTP are potentially subject to hypothetical bias in the same direction and extent, the use of marginal WTP for comparing welfare is likely to give valid results even if there is no definitive conclusion about hypothetical biases.[3] While the elicitation of hypothetical WTP may generate some bias in the general level of WTP, the experimental protocol avoids possible deception when participants choose a non-existent product.[4] Participants were also debriefed after the experiment and made aware of the fact that the products covered in the survey were not alluding to any existing market product. In the evaluation procedure, a distinction was made between orange juice fortified with vitamin D by means of nanotechnology and orange juice for which the bottle is produced by means of nanotechnology for protecting food nutrients (especially vitamin C) from

2 The number of available nanotechnology food products on the market is extremely low (Kuzma and VerHage, 2006). As there exists neither an official definition nor labelling requirements for the use of nano-materials, the number of currently available nanotechnology food products is not known. Most food companies do not communicate about the use of nanotechnologies (Greßler *et al.*, 2008).

3 By comparing hypothetical and non-hypothetical responses, Lusk and Schroeter (2004) showed that marginal WTP for a change in quality/characteristic is, in general, not statistically different across hypothetical and real payment settings. By also comparing hypothetical and non-hypothetical responses, Taylor, Morrison and Boyle (2010) indicate that WTP are not statistically different with private good experiments, but statistically different with public good experiments. Our experiment focuses on food as a private good.

4 For considerations about deception in economic experiments, see Bonetti (1998).

Table 2. Timeline of the study

	Treatment		
Steps in the experiment	Group I	Group II	Group III
General instructions, consent, entry questionnaire	✓	✓	✓
Information on orange juice	✓	✓	✓
Measure WTP_1	✓	✓	✓
General information on nanotechnology	✓	✓	✓
Measure WTP_2	✓	✓	✓
Discussion on information to choose			✓
Choose one type of information		✓	✓
• Health • Environment • Society			
Provision of information	Society	Chosen (above)	Chosen (above)
Measure WTP_3	✓	✓	✓
Exit questionnaire	✓	✓	✓

damage due to UV light. This allows the experiment to focus on two types of applications, and the protocol precisely controls the revelation of information in the laboratory.

2.3. The revealed information

During the experiment, information was communicated in several steps (Table 2), each time followed by WTP elicitations among participants. Information was successively given on separate sheets of paper.

In each stage, the speaker invited the participants to carefully read the message before indicating their WTP in a payment card format. While the complete information revealed to subjects is given in Appendix A, it is possible to sum up the content delivered at different points in the experiment as follows.

First, we provided general information about the two orange juices (A: enriched in vitamin D; B: UV-protected bottling) preceding the participants' first choices for eliciting WTP.

Second, we provided general information about the use of nanotechnology in enriching (A, in the following called nano-food) or bottling (B, in the following called nano-packaging) preceding the participants' choice 2.

Third, we gave one type of additional information about environmental, societal or health attributes linked to nanotechnology (see Appendix A). For each type of information, positive and negative aspects were revealed at the same time. Within each group, the order of positive and negative information was randomly alternated among participants.

With regard to the additional information revealed before the third round, participants were divided into three groups. Group I had no choice and received societal information. In groups II and III, participants could choose the type of additional information. After the second choice, they had three different cards on their table, each indicating a different type of information. Participants had to select the information they desired most and to indicate to the moderator the information they wished to receive. A sheet of paper with the corresponding information was given by organisers to participants according to their choices (see Appendix A). The main difference between groups II and III is a discussion that was held among participants in group III only. Participants exchanged their views on the most important type of information (health, societal and environmental information) after choice 2 and before selecting additional information preceding choice 3. Each participant in groups II and III individually chose the desired information, also after participating in the group discussion in group III. The effect of discussion is the subject of a separate paper and will not be discussed here. For the purpose of this paper, we separate the forced (group I) from the chosen (groups II and III) information. The selection of societal information for group I was decided after observing the choices previously made by groups II and III, in order to balance the priorities exhibited by the choices made by groups II and III (see the next section).

2.4. The experimental procedure

The experiment was divided into several stages as described in Table 2. Participants received general instructions and signed a consent form. They filled in an entry questionnaire on health and nutrition behaviour and on socio-demographic characteristics. After each round of information revelation, they filled in a payment card presented on a sheet of paper. Hence, they replied to three different WTP questions. Participants filled in an exit questionnaire and received EUR 20 (EUR 30) indemnity in Paris (Munich).

A multiple-price list (payment card) was used for eliciting WTP. During each choice phase, participants were asked to choose whether or not they will buy the product for prices varying from EUR 1.30 to 2.20 for each product in France and varying from EUR 0.90 to 1.80 for each product in Germany with a 10-cent interval (see Appendix B). The prices were based on a supermarket survey in France and Germany for bottled orange juices.[5] Differences in baseline WTP thus have to be evaluated in the context of country-specific different price frames. For both countries, participants had

5 In both cities, we conducted a small sampling of prices in supermarkets and discounters. In Germany, we observed prices ranging from EUR 1.09 and 1.49. The average price of one bottle of orange juice (100 per cent pure juice) was EUR 1.29. In France, we observed prices ranging from EUR 1.29 to 2.09. The average price was EUR 1.83. Using these observations for existing products, we extrapolated a price list that had a similar number of prices to be evaluated (10 prices in 10-cent intervals). It must be considered that these orange juice innovations will not necessarily fall in the same price ranges of juices currently on the market.

to fill out 10 lines for each product and for each choice. The price interval differs between both countries, reflecting the difference at the domestic level. For each price, they had to check off either 'yes', 'no' or 'maybe' regarding their purchase intents. For each product and for each round of choice i with $i = 1, 2, 3$, the WTP was determined by taking the highest price linked to a choice 'yes' (with the following highest price on the sheet of paper implying a reply 'no' or 'maybe').

Multiple-price lists were employed in this experiment to simplify the task for consumers when evaluating independently two products in several rounds. Criticisms against multiple-price lists were brought forward by Andersen *et al*. (2006). One drawback is the interval response eliciting interval data rather than point estimates for WTP. With our experiment, the 10-cent interval guarantees a sufficient degree of precision for the elicited WTP. Another disadvantage mentioned by Andersen *et al*. (2006) is the framing effect with a psychological bias towards the middle of the multiple-price list for choices made by participants. They controlled for this effect by changing the boundaries of the multiple-price list. In this paper, we did not control this framing effect by changing the boundaries, since we focus on the impact of information and message revelation.[6]

We also chose to make explicit the price frame present in the two countries. While a psychological bias seems plausible for the first round of our experiment, the anchor should remain constant in subsequent rounds so that comparison of WTP across rounds and products remains relevant. Indeed, we find in choice 1 an estimated average value of WTP for respondents with at least one 'yes' response close to the value of EUR 1.23 in Germany and EUR 1.65 in France, that is to the centre value of the price list. However, this effect tends to disappear after the revelation of information. This suggests that our methodology is relevant for estimating the WTP variation due to the revelation of information.

3. Experimental results

Table 3 shows the number of boundary bidders on the multiple-price list. At the start of the information treatment, when the nutritive properties of the juices were explained but nanotechnology was not mentioned yet, 37 consumers in France and 14 consumers in Germany were not willing to accept the fortified orange juice even at the lowest price. Regarding the nano-packaging application, there were 28 non-engaged bidders in both countries. Similarly, in the beginning, there were 13 (10) consumers accepting the nano-food product even at the highest price in France (Germany) and 13 (9) participants did so for the nano-packaging product.

6 Regarding the quality of the data, we had to exclude one participant from the German sample, because of multiple-price switches. For four participants in each France and Germany, we have three missing values for the WTP elicitations.

Table 3. Number of boundary bidders in each round of WTP evaluations (in Euros)

	France	Germany
Nano-food – lower bound[a]		
$WTP_{1j} < 1.30/0.90$	37	14
$WTP_{2j} < 1.30/0.90$	60	56
$WTP_{3j} < 1.30/0.90$	79	82
Nano-food – upper bound[a]		
$WTP_{1j} \geq 2.20/1.80$	13	10
$WTP_{2j} \geq 2.20/1.80$	13	4
$WTP_{3j} \geq 2.20/1.80$	8	3
Nano-packaging – lower bound[a]		
$WTP_{1j} < 1.30/0.90$	28	28
$WTP_{2j} < 1.30/0.90$	64	43
$WTP_{3j} < 1.30/0.90$	80	76
Nano-packaging–upper bound[a]		
$WTP_{1j} \geq 2.20/1.80$	13	9
$WTP_{2j} \geq 2.20/1.80$	8	7
$WTP_{3j} \geq 2.20/1.80$	6	6
Total number of participants	152	143

[a]The left (right) number reports the lower and upper bound in France (Germany), respectively.

Going from information round to information round reveals that the number of boundary bidders increases considerable at the lower bound, while it almost disappears at the upper bound. Considering this data structure, we analyse these results applying a two-sided tobit model, accounting for the boundary bids and allowing the estimation of the average WTP across rounds.

Let i denote the round of WTP elicitation and j the participant. Using WTP_{ij} as the dependent variable, and $\mathbf{X_{ij}}$ as the explanatory variables indicating the rounds of information, the socio-demographic and knowledge and perception variables, the tobit model can be written as

$$WTP_{ij} = \beta_0 + \boldsymbol{\beta_1 X_{ij}} + \varepsilon_{ij}, \quad (1)$$

where WTP_{ij} is bound between EUR 1.30 and 2.20 in France and EUR 0.90 and 1.80 in Germany. Given that we have three observations ($i = 1, 2, 3$) per participant, we estimate a random parameters tobit model. We estimate four models, one for each country and each product separately.

In the model, we first consider consumers' reaction to general information on nanotechnology (all participants) and the information about specific risks and benefits linked to health, environment or society.

About two-thirds of the participants, those in groups II and III, had choice of the type of information. When this choice was free, as in groups II and III, then in both countries a majority of the participants (85.3 per cent in France and 84.2 per cent in Germany) chose health as information (Table 4).

Table 4. Variables for econometric analysis and information choice (per cent of participants)

	France	Germany
Variable (per cent)		
General information$_{ij}$[a]	100	100
Unfam$_{ij}$[b]	29.8	31.5
Forced$_{ij}$[c]	32.9	29.4
Chosen$_{ij}$[d]	67.1	70.6
Type of chosen information in groups II and III (per cent)[f]		
Health	85.3	84.2
Environment	7.8	7.9
Society	6.9	7.9
GMO risk[e], mean (standard deviation)	4.050 (1.105)	4.200 (1.066)
Number of participants	152	143

[a]Dummy variable = 1, for $i = 2, 3$, indicating the participant has received general information, 0 otherwise.
[b]Dummy variable = 1, for $i = 2, 3$, if nanotechnology was unknown to participants before the study, 0 otherwise (exit questionnaire).
[c]Dummy variable = 1, for $i = 3$, if participant j was not able to choose the additional information, 0 otherwise.
[d]Dummy variable = 1, for $i = 3$, if participant j was able to choose the information, 0 otherwise.
[e]Participants' health risk perception with regard to GM food (1 = very low, . . ., 5 = very high) (entry questionnaire).
[f]Participants in groups 2 and 3 were 102 (101) in France (Germany).

On the contrary, group I was 'forced' to an additional piece of information, and this was societal information (these concerned a total of 32.9 per cent of the participants in France and 29.4 per cent of the participants in Germany).[7] Table 4 further presents the descriptive statistics of the two independent variables' unfamiliarity with nanotechnology and risk perception of GM food. Unfamiliarity with nanotechnology is a simple dummy variable that indicates whether nanotechnology was unknown to participants before the study. In our samples, 29.8 per cent of the participants in France and 31.5 per cent of the participants in Germany had not heard about nanotechnology before. The variable enters only into the estimation for $i = 2, 3$, because nanotechnology was not mentioned before eliciting WTP$_{1j}$. The variable is denoted as Unfam$_{ij}$ and all values of Unfam$_{1j}$ are hence coded as zero. We also include the perception of risk posed by GM food (evaluated on a five-point Likert scale) as a proxy variable regarding acceptance of new food technologies (Visschers *et al.*, 2007; Costa-Font, Gil and Traill, 2008 for a review; Kahan *et al.*, 2009).

Table 5 presents the results of the tobit estimations by nanotechnology application and country. Dependent variables are WTP$_{ij}$ for nano-food and WTP$_{ij}$ for nano-packaging. The number of observations for each of the four

7 One must consider that the forced reception of information may have different impacts from selected choice of information. For space consideration and because the focus is on intercountry/interproduct comparison, this paper only considers the assurance that information provided was of primary interest to participants.

Table 5. The effect of information on WTP according to application and country (tobit model parameter estimates)

	Nano-food		Nano-packaging	
	France	Germany	France	Germany
Constant	2.157***	1.369***	2.365***	1.142***
	(0.168)	(0.118)	(0.149)	(0.126)
General information	−0.118	−0.184***	−0.182***	0.001
	(0.082)	(0.052)	(0.071)	(0.056)
Forced	−0.104	−0.003	−0.077	−0.029
	(0.107)	(0.074)	(0.093)	(0.079)
Chosen	−0.168*	−0.255***	−0.201**	−0.260***
	(0.094)	(0.060)	(0.084)	(0.063)
Unfam	−0.048	−0.120**	−0.147***	−0.136**
	(0.092)	(0.059)	(0.083)	(0.062)
GMO risk	−0.120***	−0.033*	−0.111***	−0.066***
	(0.020)	(0.012)	(0.026)	(0.021)
Gender	−0.040	0.023	−0.019	0.059
	(0.066)	(0.043)	(0.058)	(0.046)
Age	−0.001	0.002	−0.005***	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Income/1,000	−0.025	−0.005	−0.015	0.001
	(0.016)	(0.013)	(0.014)	(0.013)
Number of observations	330	356	333	356
Log L	−259.4805	−198.076	−236.9002	−218.8223
χ^2 (9)	199.260***	179.151***	231.948***	145.593***
Sigma	0.527	0.359	0.465	0.386

Standard errors are reported in parentheses.
*Significant differences at the 10 per cent level.
**Significant differences at the 5 per cent level.
***Significant differences at the 1 per cent level.

estimations results from the number of participants across three rounds, correcting for missing values.

It was assumed that a new, still unknown technology with high levels of uncertainty, as is the case for nanotechnology food applications, may make consumers rely on previous evaluations of other already known food technologies, such as genetic modification in food. In both countries and for both products, higher risk judgements of GM food are linked to a significantly lower WTP for the nano-food and nano-packaging. Calculating the marginal effects, we found that the effects are smaller in Germany than in France.[8]

8 The marginal effects for the effect of GM-food risk perception (GMO) are −0.061 and −0.021 for nano-food and −0.062 and −0.040 for nano-packaging in France and Germany, respectively (see Appendix C). All these values are statistically significant.

Interpreting the variable as a proxy to the general attitude and risk perception with regard to new food technologies shows that people being critical regarding the safety of genetic modification are also critical in accepting nanotechnology. The socio-demographic variables are not statistically significant but for age in the model on WTP for nano-packaging in France, where the impact is negative. We include them nevertheless to avoid bias due to omitted variables.

To help the further interpretation of the results of the tobit model, Table 6 provides the estimated average WTP in euros for the two different types of orange juice in France and Germany.

The values are the mean prediction per product and elicitation round calculated from the tobit model in Table 5. Considering the mean prediction value in the first round, WTP_{1j}, the table shows that French consumers are willing to pay more for the packaging application compared with the food application, while the German consumers place a higher utility on the fortified orange juice compared with the juice with improved packaging.

3.1. The effect of general information on nanotechnology

Previous research has shown that consumers' reaction to nanotechnology in the food sector depends on the type of application (Siegrist *et al*., 2007, 2008). While in both countries consumers decrease their WTP successively with more information, their reaction to general information on nanotechnology for the two types of applications are quite different (see the parameters to General Information in Table 5 and $WTP_{2j} - WTP_{1j}$ in Table 6) . The revelation of general information about nanotechnologies leads to a statistically significant decrease in WTP for the juice with nano-vitamins in Germany and for nano-packaging application in France. The decrease in WTP for nano-food is not significant in France, neither is the small increase in WTP for the nano-packaging application in Germany (Table 5). The incidences of a significant decrease in WTP are observed despite the health benefit expressed as 'a better absorption of the vitamin' and the protection of 'food nutrients from damage due to UV light' clearly mentioned in the first general message about nanotechnologies (see Appendix A). Similar to findings from previous studies (BfR, 2008a; Vandermoere *et al*., 2010b), German consumers seem to be more reluctant to nano-food applications than to nano-packaging applications. For French consumers, however, an inverse picture emerges.

It further seems that the higher the initial product utility is (as revealed in WTP_{1j}), the stronger the negative effect on WTP of getting to know that the product was produced by means of nanotechnology. That is, the constant is higher for the nano-packaging application compared with the nano-food application in France, while the relationship is reversed in Germany.

The tobit regressions further confirm the findings presented in Table 3 regarding the inverse reaction due to general information on nanotechnology in France and Germany. As reported in Table 3, the number of participants refusing the product due to getting to know that it was produced by means of nanotechnology increases more for the nano-packaging application

Table 6. Average WTP and change in average WTP due to information provided: predictions calculated from tobit models (Euros)

	WTP_{1j}	WTP_{2j}	WTP_{3j}	$WTP_{2j} - WTP_{1j}$	$WTP_{3j} - WTP_{1j}$
France					
Nano-food	1.623	1.555	1.488	−0.068	−0.135
Nano-packaging	1.673	1.546	1.475	−0.127	−0.198
Germany					
Nano-food	1.269	1.115	1.027	−0.154	−0.242
Nano-packaging	1.183	1.157	1.057	−0.026	−0.126

(+36) compared with the nano-food application (+23) in France. German participants show an inverse reaction with an increase of +42 for the nano-food application compared with +15 for the nano-packaging application. In the tobit regressions, the impact of general information on nanotechnology is not significant for the nano-food application in France and for the nano-packaging application in Germany.

Regarding the effect of unfamiliarity with nanotechnology, we observed that around 30 per cent of the participants in France and Germany had never heard about nanotechnology before and the participants who were already familiar with nanotechnology had rudimentary knowledge in France and in Germany (see also Vandermoere *et al.*, 2010a, 2010b, with data coming from a web survey). Familiarity with nanotechnology is found to play a role in accepting nanotechnology. German consumers who had never heard about nanotechnology show a significantly stronger decrease in WTP for both applications compared with people who were somewhat familiar with it. In France, this reaction is only found for nano-packaging.

3.2. The effect of additional specific information on WTP

In both countries and for both applications, the forced information in group I (information on the impact for society) has no impact on WTP.

Regarding chosen information, which was health information in about 85 per cent of the cases, it significantly decreases the WTP for both applications and in both countries. The reluctance to accept the products is hence particularly salient when the type of detailed information is chosen by participants. Eventually, Figure 1 shows the distribution between indifferent consumers (shift in $WTP_{3j} - WTP_{1j} = 0$), consumers who decrease their WTP as a consequence of nanotechnology information (shift in $WTP_{3j} - WTP_{1j} < 0$) and consumers who increase their WTP (shift in $WTP_{3j} - WTP_{1j} > 0$) for both countries and products. The majority of participants in both countries decrease their WTP and Figure 1 hints to important group differences for nano-food and nano-packaging across countries where a relatively larger share of consumers decrease their WTP for nano-packaging in France and for nano-food in Germany. Overall, somewhat more French consumers are willing to increase

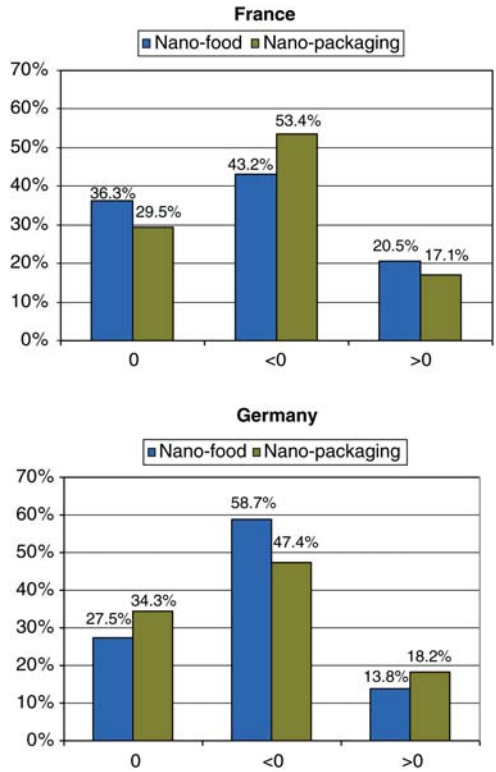

Fig. 1. Percentage of respondents in WTP-shift groups ($WTP_{3j} - WTP_{1j}$).

their WTP when compared with German consumers. This raises the question of the importance of this segment of consumers with $WTP_{3j} - WTP_{1j} > 0$ for allowing the emergence of nano-products and covering the sunk costs linked to the research and development of a new technology.

4. Conclusion

The results of this paper show that many participants in the experiment are reluctant to accept nanotechnology applications in food products. Despite limitations of the sample size that could be covered in a laboratory experiment of information treatment, we concur with Falk and Heckmann (2009) that experimental results are useful in establishing causal relationships between variables. The results underline the inclination of many French and German consumers to reject nanotechnology innovations. Similar to previous research, we could show that the type of food application is important for the acceptance of nanotechnology. However, it seems that application-specific reactions differ between countries and may depend on prior beliefs and on familiarity. These prior beliefs may differ between countries, especially for food choices,

which are linked to long-term country-specific traditions (see, e.g., Brunsø and Grunert, 1998; Grunert, Brunsø and Bredahl, 1998) or differing views on the role of the state in securing consumer protection in France and in Germany (Trumbull, 2006).

Furthermore, the higher the initially perceived benefits (revealed in WTP_{1j}), the stronger the absolute decrease in WTP will be due to general information on nanotechnology. Hence, it appears that positively valued product-related benefits are 'deleted' by the fact that the juices have been produced by means of nanotechnology. Thus, especially in the first phase of food nanotechnology innovations, it may be hard for regulators to act homogeneously at the European level. National agencies might be of special importance for communication and consumer information. However, we could further show that product-related dependence which was found to differ between the two countries seems to disappear with more information. This implies that a unified European strategy is likely to be more efficient in the long run, as products become better known to consumers.

Results also show that food safety and its link to human health play a prominent role in consumers' concerns in France and in Germany. For both products, health information was the most-sought additional information and it significantly decreased respondents' WTP. In both countries, only very few respondents (about 8 per cent) chose environmental or societal information. It is often expected that consumers' reactions to food nanotechnology will be analogous to the negative reaction to GM food. We can show that a high-risk perception of GM food correlates with lower WTP of nano-food and nano-packaging, both in France and in Germany. Results have further shown that between 13 and 20 per cent of the participants (depending on the country and application) increased their WTP after additional information. This points to a potential market for nanotechnology food products in both countries. Labelling of products produced by means of nanotechnology may thus be beneficial not only for consumers who want to avoid buying nanotechnology products, but also for consumers aiming at benefiting from recent nanotechnology innovations.

Next to differing reactions with regard to the type of application, the effect of familiarity with nanotechnology is important. It plays a significant role in Germany for both products but only for nano-packaging in France. Possibly, the largely positive framing of nanotechnology in the German media (BfR, 2008b) may attenuate consumers' negative reactions towards risk information, and positive general beliefs may confirm the content of the benefit information. In addition, it might be that people in Germany who had never heard about nanotechnology are less interested in technological innovations because of a generally more negative attitude towards science and technology. This positive relationship between scientific and technological openness and familiarity has been found in the study by Kahan *et al*. (2009) and Vandermoere *et al*. (2010b). For France, however, familiarity only plays a role in the initially high value given to nano-packaging.

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Appendix A

The precise messages are translated from the original German and French. Questionnaires were the same in both countries except for the price ranges. The version below presents the German one; the French price range was between EUR 1.30 and 2.20.

A.1. The initial information before choice 1

In what follows, we will present you information about two pure orange juices sold in 1-liter bottles (100 per cent pure juice). On the market, the average price of this type of orange juice varies between EUR 0.90 and 1.80.

Orange juice A	**Orange juice B**
	
This orange juice is fortified with vitamin D. According to scientific estimations 90 per cent of Europeans have vitamin D intakes below recommendations.	This orange juice is filled in a plastic bottle that is fabricated in a way to reduce the juice's exposure towards UV light. Exposure to UV light considerably reduces the amount of important food nutrients like vitamin C.

A.2. The general information before choice 2 (on a new and separate sheet)

Please read carefully the following information:

General information about nanotechnology

Nanotechnology refers to materials, systems and processes which exist or operate at the scale of atoms and molecules. This is a scale between 1 and 100 nanometres (nm). One nanometre is one millionth of a millimetre (mm).

Materials at the nano-scale show novel properties that lead to novel applications in diverse fields like medicine, cosmetics, biotechnology, energy production and environmental science. There is uncertainty regarding how nano-materials may interact with human health and the environment.

Nanotechnology offers new opportunities for food industry application.

Manufactured nano-materials are already used in some food products, nutritional supplements and food-packaging applications. Two examples in development are the two orange juices that have been already presented to you.

Orange juice A	**Orange juice B**
	
Orange juice A is fortified with vitamin D by means of nanotechnology. Vitamin D is enclosed in a nanoscale capsule that allows a better absorption of the vitamin in the human body.	Orange juice B is produced by means of nanotechnology. The bottle is imbued with nano titanium dioxide particles that protect food nutrients from damage due to UV light.

A.3. The different types of information before choice 3 (on a new and separate sheet of paper each)

A.3.1. Society

If negative information was presented first, the message was:

Please read carefully the following information:

Implications on the society

There is some concern that nanotechnology might further concentrate the power of big multinational enterprises in the food and agriculture sector. This will further erode local farmers' control of food production.

On the other hand, advocates think that nanotechnology will ensure food security as it enables higher crop yields and prevents losses after the harvest.

If positive information was revealed first, the message was:

Please read carefully the following information:

Implications on the society

Advocates think that nanotechnology will ensure food security as it enables higher crop yields and prevents losses after the harvest.

On the other hand, there is some concern that nanotechnology might further concentrate the power of big multinational enterprises in the food and agriculture sector. This will further erode local farmers' control of food production.

A.3.2. Environment

If negative information was presented first, the message was:

Please read carefully the following information:

> Implications on the environment
>
> It is worried that nano-particles will be released in the environment during production, consumption and discharge of the products and may pose risks. It has, for example, been found that manufactured nano-particles can have toxic effects on aquatic organisms.
>
> On the other hand, nanotechnology may help to reduce pollution from efficient use of materials and it is hoped that nanotechnology allows the development of new ways to transform and detoxify a wide variety of environmental contaminants.

If positive information was presented first, the order of both paragraphs were switched as shown in the case of 'implications on the society'.

A.3.3. Human health

If negative information was presented first, the message was:

Please read carefully the following information:

> Implications on human health
>
> Science does not know yet what levels of nano-exposure we are currently facing and what levels of exposure could harm our health. In toxicological studies with mice and rats, e.g. some nano-particles have been found to be toxic to cells and damage organs.
>
> On the other hand, nanotechnology allows enclosing nutrients like vitamins in a nano-scale capsule which improves their absorption and nutrients can be integrated into food without changing the products taste or texture.

If positive information was presented first, the order of both paragraphs were switched as shown in the case of 'implications on the society'.

Appendix B: Multiple-price list

The version below presents the German one; the French price range was between EUR 1.30 and 2.20.

In the following, you will be asked for your willingness to buy each of these products. Please consider the products independently of each other.

> For each line, check off either yes, no or maybe. Please check off one option for every price.

Your choice

Orange juice A				**Orange juice B**			
							
Orange juice A is fortified with vitamin D by means of nanotechnology. Vitamin D is enclosed in a nanoscale capsule that allows a better absorption and mobilisation of the vitamin in the human body.				Orange juice B is produced by means of nanotechnology. The bottle is imbued with nano titanium dioxide particles that protect food nutrients from damage due to UV light.			
Remind: On the market, the average price of this type of orange juice varies between EUR 0.90 and 1.80.				Remind: On the market, the average price of this type of orange juice varies between EUR 0.90 and 1.80.			
Would you be willing to buy this orange juice at				Would you be willing to buy this orange juice at			
	Yes	No	Maybe		Yes	No	Maybe
EUR 0.90	□	□	□	EUR 0.90	□	□	□
EUR 1.00	□	□	□	EUR 1.00	□	□	□
EUR 1.10	□	□	□	EUR 1.10	□	□	□
EUR 1.20	□	□	□	EUR 1.20	□	□	□
EUR 1.30	□	□	□	EUR 1.30	□	□	□
EUR 1.40	□	□	□	EUR 1.40	□	□	□
EUR 1.50	□	□	□	EUR 1.50	□	□	□
EUR 1.60	□	□	□	EUR 1.60	□	□	□
EUR 1.70	□	□	□	EUR 1.70	□	□	□
EUR 1.80	□	□	□	EUR 1.80	□	□	□

If you filled out everything, please put the questionnaire in the coloured sheet of paper.

Appendix C

Table C.1. The effect of information on WTP according to application and country (marginal effects)

	Nano-food		Nano-packaging	
	France	Germany	France	Germany
Constant	1.098***	0.865 ***	1.328***	0.861***
	(0.103)	(0.085)	(0.104)	(0.087)
General information	−0.060	−0.117***	−0.102***	0.001
	(0.041)	(0.033)	(0.040)	(0.034)
Forced	−0.053	−0.002	−0.043	−0.017
	(0.055)	(0.047)	(0.052)	(0.048)
Chosen	−0.086*	−0.161***	−0.113**	−0.157***
	(0.047)	(0.037)	(0.047)	(0.038)
Unfam	−0.024	−0.076**	−0.082***	−0.082**
	(0.047)	(0.037)	(0.046)	(0.037)
GMO risk	−0.061***	−0.021*	−0.062***	−0.040***
	(0.015)	(0.012)	(0.015)	(0.013)
Gender	−0.020	0.014	−0.011	0.035
	(0.034)	(0.027)	(0.033)	(0.028)
Age	−0.000	0.000	−0.003***	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Income/1,000	−0.013	−0.032	−0.008	0.000
	(0.008)	(0.008)	(0.008)	(0.008)

Standard errors are reported in parentheses.
*Significant differences at the 10 per cent level.
**Significant differences at the 5 per cent level.
***Significant differences at the 1 per cent level.