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The Effect of Information Choice and Discussion on Consumers' Willingness-to-Pay for Nanotechnologies in Food

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We evaluate the impact of different information sequences on participants' hypothetical willingness to pay (WTP) for food produced using nanotechnology. In three treatment groups, information on the health, societal, or environmental impact linked to nanotechnology was revealed in different sequences: an imposed order, a chosen order, and a chosen order after a discussion among participants. Results show that information choice is important. While in the imposed order, the first information revealed has no effect on WTP, the information chosen first has a strong impact. Discussion has no further impact. Health information was a priority and significantly decreased WTP, while societal and environmental information did not significantly influence WTP.

Key words: discussion, experimental economics, food nanotechnology, information choice, willingness to pay

Introduction

New food technologies can be controversial and public debates muddled. The lack of clear information threatens consumer confidence, compromising the acceptance of new products despite their social benefits. Understanding consumers' concerns is important for improving public debates and regulations. This study investigates the impact of information sequencing on consumers' willingness to pay (WTP) for an orange juice fortified with vitamin D using nanotechnology.

Nanotechnology is a new technology that deals with materials, systems, and processes at the scale of atoms and molecules (European Commission, 2004). Materials at the nanoscale show novel properties, which are used to create novel applications in diverse fields (European Commission, 2005; Renn and Roco, 2006). In food, nanotechnology is applied to improve food packaging, safety, or health and nutrition (Joseph and Morrison, 2006). For example, nanotechnology for food packaging can reduce UV-light exposure or microbial growth. Moreover, nanosensors able to detect pathogens or contaminants improve food safety (Weiss, Takhistov, and McClements, 2006) and through encapsulation, nanotechnology can improve fortification with functional ingredients (Chen, Remondetto, and Subirade, 2006; Weiss, Takhistov, and McClements, 2006).

However, the novel properties of nanomaterials that allow many promising applications are accompanied by possible risks and high rates of uncertainty (Dreher, 2003; Hoet, Brüske-Hohlfeld,

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and Salata, 2004). Given the very limited information regarding consumers' toxicological exposure to nanoparticles and the inability to detect nanomaterials in food, scientific risk assessments of nanotechnologies are characterized by high levels of uncertainty (European Food Safety Authority, 2009).

We develop an experiment in which participants are asked to evaluate an orange juice fortified with Vitamin D using nanotechnology; as part of the experiment, participants receive different information scenarios. The purpose of this paper is to evaluate the impact of different information sequences on consumer choice of products involving innovations, like nanotechnology, that may have uncertain consequences for health, the environment, and society. Participants' reaction to an imposed order of information is compared to participants' reaction to chosen sequences of information with and without a discussion among participants.

The opportunity to choose information should help people consider potential information content. Voluntary access may be a way to guarantee effectiveness, since participants can choose to focus directly on their priority. Given the relatively high costs of deliberative methods, such as group discussions, compared to surveys, we investigate whether these more elaborate methods add value compared to a simple information choice.

Results show that information choice influences WTP. Information considered most important by consumers affects WTP, while information provided first in an imposed order does not (unless consumers consider that information to be important). The chosen order of information suggests that participants have a real concern for the health impacts of nanotechnology. Health information is a priority in participants' information choice, and information on potential health risks significantly decreases WTP for orange juice; societal and environmental information do not significantly influence WTP.

WTP for the group receiving information in an imposed order (with health information revealed last) does not change significantly until health information is revealed, highlighting that the weight participants give to a question or specific characteristic is more important than the potential for diminished attention to new information at the end of the experiment. Furthermore, discussion has no significant effect on WTP. Our results raise questions about the additional benefit of discussion among participants when measuring consumers' valuation of novel products.

This paper contributes to the literature by providing what we believe to be the first estimates of WTP related to nanotechnologies bringing direct benefits to consumers. This differs from the literature about WTP for first-generation GMOs that dealt with products that did not change food product characteristics (see Noussair, Robin, and Ruffieux, 2002; Rousu et al., 2004, 2007) and builds on research about second-generation GMOs where the application of genetic modification yields improved consumer product characteristics (e.g., Lusk, 2003). By introducing positive and negative aspects of a new technology, our paper differs from previous research considering the effect of uncertainty on consumers' valuation of food. Some studies focus on information itself, with emphasis on information precision (Hayes et al., 1995), ambiguity (Huffman et al., 2003, 2007; Rousu et al., 2004, 2007), length (Wansink, Sonka, and Hasler, 2004) or novelty of content (Bougherara and Combris, 2009).

This paper complements work done by Hu et al. (2006), which observed that voluntary access to information influences consumer choice and concluded that the impact of information accessed voluntarily is likely a better representation of information effects, because information provided in an experiment may not always be accessed by consumers in actual field decisions. This paper differs in that the option to choose the sequence of messages is compared to alternative ways of revealing information.

By eliciting WTP with and without discussion, this paper links to research on group discussion and consumer conferences (Walls, Rowe, and Frewer, 2011). Compared to surveys, interactive approaches are supposed to show a more accurate picture of opinions, as they allow time and opportunity for reflection (Dolan, Cookson, and Ferguson, 1999). The effect of discussion on consumer valuation has previously been analyzed in the context of public goods (Dolan, Cookson,

and Ferguson, 1999; Macmillan et al., 2002; Spash, 2007). Dolan, Cookson, and Ferguson (1999) found systematic differences in public opinion about health care prioritization before and after having the opportunity to discuss. Macmillan et al. (2002) emphasized the advantage of group-based approaches over individual interviews for the evaluation of unfamiliar environmental goods. Our paper mitigates these previous views, since the participant discussion in our experiment has no significant effect on WTP.

Methodology

The experiment was conducted in Munich, Germany in multiple sessions in January and February, 2009. A sample of 143 participants was randomly selected based on the quota method, allowing participant selection representative of the gender, age, and socio-economic status for the population of the city. Participants were invited by letter to participate in a study about nutrition behavior.

The experiment focused on WTP for a one-liter bottle of orange juice enriched with vitamin D through nanotechnology. Because of a lack of labeling requirements and information in the market, it was not possible to identify nanotechnology food products on the German market at the time of the experiment. We thus defined the nanoproduct based on a review of the literature leading us to select the most likely type of nanotechnologies applied to food, namely food fortification. As the product did not exist, no auction/choice mechanism was organized at the end of the experiment for selling products based on the choices. The consent form signed at the beginning of the experiment clearly stated that participants would receive a €30 indemnity. We did not make any reference to auction mechanisms and products to purchase at the end of the experiment. This protocol elicits hypothetical WTP but avoids possible deception of participants "choosing" a non-existent product. Participants were also debriefed after the experiment to restate that the product presented in the hypothetical valuation questions did not exist on the market.[1]

The elicited WTPs are hypothetical and potentially subject to hypothetical bias. However, based on evidence in the literature, the risks of possible hypothetical bias regarding welfare measures are very limited, since the marginal WTP (namely the difference between WTP expressed under different treatment and in successive rounds of information) is used for measuring the impact of different information sequences. By comparing hypothetical and non-hypothetical responses, Lusk and Schroeder (2004) show that marginal WTP for a change in information about quality or a characteristic is generally not statistically different across hypothetical and real payment settings. Moreover, Camerer and Hogarth (1999) show that performance-based financial incentives have little effect on mean responses. In our econometric estimations, all bids are potentially subject to bias in the same direction and to the same extent, implying that our comparison across different sequences of information and their marginal effect yields valid results.

During the experiment, pieces of information were successively communicated before measuring consumers' WTP using a multiple price list. The different types of information concerned the same orange juice enriched with vitamin D. Bottles of orange juice were neither displayed, nor sold. Only pictures of the one liter bottle were printed in color.

Successive pieces of information were given on individual paper sheets. Figure 1 presents an overview of the experiment timeline and design.

Complete information revealed is given in an appendix available at www.mcr.wi.tum.de/index.php?id=84. Information treatments were as follows:

1. General information about the orange juice without mentioning nanotechnology preceding the participant's choice 1 for eliciting WTP.

2. General information about nanotechnologies preceding the participant's choice 2.

[1] For considerations about deception in economic experiments see Bonetti (1998).

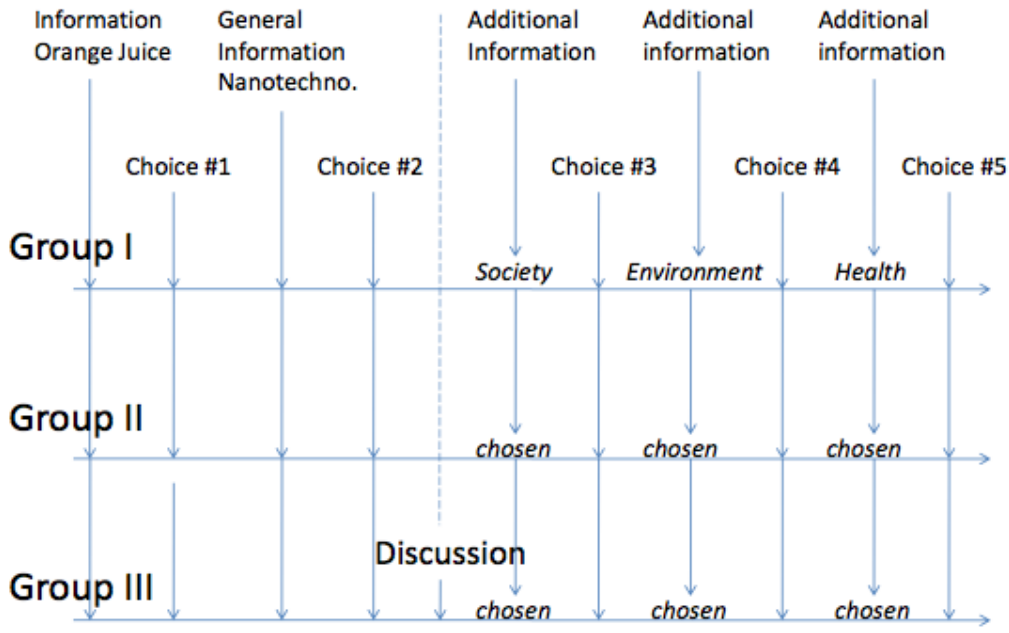

Figure 1. Timeline

3. Successive additional information about possible environmental, societal, and health attributes linked to nanotechnology. Only one type of information was revealed before each of choices 3, 4, and 5. Each piece of information included positive and negative aspects of nanotechnology. Within each group, the order between positive and negative information was randomly alternated among participants.

Participants were divided into three groups that differed in the order and the way these additional types of information before choices 3, 4, and 5 were revealed. To control for the socio-demographic composition across the three groups, participants were split at random. We did this by equally allocating the timing of sessions (morning/evening) across groups. For each group, there were multiple sessions: four for Group I, four for Group II, and seven for Group III. The size per session for Groups I and II varied between fifteen and eighteen participants. In order to allow a lively discussion and to make sure that all participants could participate in the discussion, the size per session for Group III was smaller, between six and ten participants. Sessions for Groups I and II lasted between fifty-five and seventy minutes, and for Group III between sixty-five and eighty minutes. We made sure that the share of morning and evening sessions was equal for each group, as it is assumed that people from different socio-economic groups have different schedules.

In Group I ($N = 42$), participants had no choice about the order of information. The imposed order was (1) societal, (2) environmental, and (3) health information. This specific order was selected because it counterbalanced priorities expressed by choices made by Groups II and III.

In Groups II ($N = 52$) and III ($N = 49$), participants could individually choose the additional type of information. The main difference between Groups II and III was a discussion after the second choice and before additional information selected by participants prior to the third choice. Only Group III had the possibility to exchange ideas in a discussion after the choice 2. The discussion lasted between five and thirteen minutes (ten minutes on average). The discussion focused on the question of what participants considered the most important type of information (health, societal,

Table 1. Descriptive Statistics

	Group I	Group II	Group III	Munich
Gender (%)				
Female=0	38.1%	55.8%	67.3%	51.46%
Male=1	61.9%	44.2%	32.7%	48.54%
Age in years				
mean	46.36	45.62	45.74	41.39
st. dev.	(15.64)	(13.55)	(14.35)	
Household's monthly net income[a]				
mean	2197.56	2690	2822.34	1928.752[b]
st. dev.	(1052.08)	(1892.33)	(1728.09)	

Notes: [a] As income was asked in form of intervals the interval midpoints were selected for forming variables of the econometric analysis.
[b] Per capita income.

or environmental information). The session moderator opened the discussion by asking "what is the most important information for you and why?"

During each choice procedure, participants were asked to choose whether or not they would buy the product for prices varying from €0.90 to €1.80. For each price, they had to check off either "yes," "no," or "maybe" regarding their purchase intentions. For each round of choice i with $i = 1,2,3,4,5$, the WTP was determined by taking the highest price linked to a choice "yes."

Results

Table 1 details the socio-demographic variables of the three groups with averages in the last column. Some differences exist among the groups with regards to gender and household income. Groups II and III include more women than the average population of Munich, and the mean income levels of Groups II and III are higher compared to Group I. With 143 participants, randomization across the three groups is imperfect and does not impede a residual heterogeneity. The econometric work allows us to downplay the impact of these variables on WTP elicitation. Indeed, we see that age and income are not statistically significant for explaining WTP levels, and that the coefficient for gender is the lowest among significant variables (see table 3).

Table 2 illustrates that a vast majority of participants in Groups II and III selected additional information on health as their first choice. Information about the environment is the most frequent second choice, while information about society is the last choice. A comparison of Groups II and III reveals that, after deliberation, there is a slight increase in the priority given to information on the implications for society. Society is chosen as a first priority by 10.5% of the participants in Group III, but by only 4.2 % of participants in Group II. Fewer participants in Group III (79.2%) chose health information as the most important information compared to participants in Group II (89.6%). This difference was not found to be statistically significant in Chi-square tests.

The determinants of WTP are investigated by directly controlling the effects on groups. As the dependent variable is right- and left-censored, we use a Tobit regression to estimate the mean WTP per group and per information treatment. To do so, we regress each participant's WTP on rounds of information and groups. WTP_{ij} denotes participant j's WTP under each choice i ($i = 1,2,3,4,5$). The different rounds of choices following the revelation of information are taken into account via dummy variables C_2, C_3, C_4, and C_5, respectively equal to one for choices 2, 3, 4, or 5, and 0 otherwise. The dummy variable C_1 is omitted (before mentioning nanotechnology) and used as the reference level. C_2 is the dummy variable for the round focusing on general and short information about nanotechnologies. C_3, C_4, and C_5 are the dummy variables for the successive rounds where the detailed messages are imposed on Group I and individually chosen by participants of Groups II and

Table 2. Choice Order of Additional Information in Percentage of Respondents

	Group II	Group III
1st Choice		
Health	89.6%	79.2%
Environment	6.3%	10.4%
Society	4.2%	10.5%
2nd Choice		
Health	4.2%	14.6%
Environment	66.7%	64.6%
Society	29.2%	20.9%
3rd Choice		
Health	6.3%	6.3%
Environment	27.1%	25.1%
Society	66.7%	68.7%

III. The group is taken into account by specific dummy variables that are used to measure treatment effects. Group II is used as the reference level and the estimated coefficients on the two other groups with dummy variables, Groups I and III, are compared to it. Furthermore, the socio-demographic variables gender, age, and income were included in the estimation.

Using WTP_{ij} as the dependent variable, X_{ij} as the variables indicating the rounds of information, groups, and the socio-demographic variables, the Tobit model can be written as:

$$WTP_{ij} = \beta_0 + \beta_1 X_{ij} + \varepsilon_{ij}, \tag{1}$$

where WTP_{ij} is bound between €0.90 and €1.80.

Table 3 shows the parameter estimates together with the derived marginal effects. Marginal effects have been calculated at the sample means and correspond in significance and direction to the parameter estimates.

Estimated coefficients on dummy variables C_2, C_3, C_4, and C_5 are negative and statistically significant at the 1% level. This demonstrates the negative association linked to nanotechnology, even though messages balanced risk and benefit information. The general and short information on nanotechnology (with the variable C_2) leads to a statistically significant decrease in WTP. This confirms that short information may have a real impact when innovation involves food (see Wansink, Sonka, and Hasler, 2004). Additional information also leads to an additional decrease in the WTP, since the coefficients linked to C_3, C_4, and C_5 are negative and increasing in absolute magnitude.

The imposition of the information order for Group I, with health information revealed last (see Figure 1), leads to a significant difference compared to Group II. The positive and significant coefficients 0.217 and 0.181 linked to both variables $C_3\times$ Group I and $C_4\times$ Group I show that the negative effects of information captured by variables C_3 and C_4 are mitigated for Group I compared to Groups II and III when societal and environmental information are revealed first. This difference in Group I disappears when health information is revealed, since the variable $C_5\times$ Group I has no significant impact. Health appears to be the priority criterion among the lot of information. Eventually, a positive coefficient linked to $C_4\times$ Group I shows that the choice of health information by many participants of Group II as first choice before the third round (see table 2) reinforces the negative perception of environmental or societal information revealed in the fourth round and linked

Table 3. Tobit Estimations of WTP for Fortified Orange Juice

Variable	Coefficient (Std. error)	Marginal effects (Std. error)
Constant	1.286***	0.624***
	(0.082)	(0.050)
C_2	−0.242***	−0.117***
	(0.055)	(0.026)
C_3	−0.511***	−0.248***
	(0.084)	(0.041)
C_4	−0.511***	−0.248***
	(0.085)	(0.041)
C_5	−0.548***	−0.266***
	(0.086)	(0.041)
$C_3\times$ Group I	0.217**	0.105**
	(0.105)	(0.051)
$C_3\times$ Group III	0.075	0.036
	(0.104)	(0.050)
$C_4\times$ Group I	0.181*	0.088*
	(0.106)	(0.051)
$C_4\times$ Group III	0.008	0.004
	(0.106)	(0.052)
$C_5\times$ Group I	0.089	0.043
	(0.110)	(0.053)
$C_5\times$ Group III	0.012	0.006
	(0.109)	(0.053)
Gender	0.126**	0.061
	(0.039)	(0.019)
Age	−0.002	−0.005
	(0.001)	(0.006)
Income/1000	−0.011	−0.001
	(0.012)	(0.001)
Log likelihood	-411.37	

Notes: ***, **, * denote significant differences at the 1%, 5% and 10% level, n=675.

to variable C_4 in table 2. The attention to additional information seems therefore contingent on health information previously revealed.

Results do not significantly differ between Groups II and III, since coefficients linked to the variables $C_3\times$ Group III, $C_4\times$ Group III, and $C_5\times$ Group III are not statistically significant. Discussion in Group III preceding the third elicitation of WTP leads to no significant difference compared to Group II. Questions and concerns expressed in the discussions among participants are not reflected in different WTP levels compared to Group II. Of the socio-demographic variables, only gender was significant, with men having a higher WTP for the orange juice fortified by means of nanotechnology as compared to women.

Based on the Tobit model reported in table 3, we calculated the mean WTP in euros for each group and round $WTP_{i.}$ for one bottle of fortified orange juice. These are reported in table 4 together with the percentage of respondents identified at the upper or lower limit of the price range in the original data. For each group, the share of participants not choosing the product–even at the lowest proposed price–increases, while the percentage of respondents willing to pay €1.80 or more

Table 4. Tobit Estimates of Average WTP and Percentage of Respondents Selecting < 0.90 and ≥ 1.80 € by Group and Information Round

	WTP_1	WTP_2	WTP_3	WTP_4	WTP_5
GROUP I					
Estimated $WTP_{i.}$ in €	1.282	1.128	1.098	1.079	1.022
% with $WTP_{ij} <$ €0.90	12.8%	37.5%	46.3%	51.2%	63.4%
% with $WTP_{ij} \geq$ €1.80	7.7%	2.5%	2.4%	4.8%	0.0%
GROUP II					
Estimated $WTP_{i.}$ in €	1.266	1.114	0.995	0.994	0.983
% with $WTP_{ij} <$ €0.90	3.9%	33.3%	64.7%	68.0%	78.6%
% with $WTP_{ij} \geq$ €1.80	5.9%	3.9%	2.0%	2.0%	2.0%
GROUP III					
Estimated $WTP_{i.}$ in €	1.254	1.103	1.014	0.991	0.981
% with $WTP_{ij} <$ €0.90	14.6%	49.0%	61.2%	69.4%	71.4%
% with $WTP_{ij} \geq$ €1.80	8.3%	2.0%	2.0%	2.0%	2.0%

decreases. A remarkable difference between the groups is the relatively large share of participants in Group III who are unwilling to buy the orange juice even at the lower bound of €0.90 in the first round, before information on nanotechnology is given. However, the increase of the share of participants dropping out of the market due to general information on nanotechnology is about the same in all three groups. Furthermore, in Group II, where 89.6% selected health information before the third elicitation of WTP, the increase in the share of participants dropping out of the market increased by 33.3% compared to Group III, where this share increased only by 10.2%.

For Groups II and III, the average WTP are considered irrespective of the type of message that was selected before measuring WTP_{3j}, WTP_{4j}, and WTP_{5j}. However, as shown by table 2, 93.8% of participants in Groups II and III selected health information for the first choice and 65.65% selected environmental information for the second choice. For Group I, the information order was society-environment-health. WTP_{1j} reveals the WTP for the orange juice before mentioning nanotechnology and WTP_{2j} the WTP after the first round focusing on general and short information about nanotechnologies.

To facilitate the interpretation of the impact of the different messages, we report in table 5 the estimated differences in WTP (based on the Tobit estimates of table 3). Whereas in Group I the last round of information (health information) leads to the strongest decrease in mean WTP after general information on nanotechnology, the first round of specific information in Groups II and III (health information, for the majority) leads to a stronger decrease in WTP ($WTP_3 - WTP_2$) than the second and third round of specific information. Estimated average WTP decreases after the revelation of information on health even if this information is balanced between benefits and risks. This additional information reinforces the initial concern or reluctance observed after the revelation of general information on nanotechnology.

Results show that consumers hesitate when nanotechnologies are mentioned in a short message and that they focus on safety. Ambiguity surrounding the technology dissolves after the health message, which is directly chosen by Groups II and III, but is last for Group I. Thus, the information considered most important by consumers (as indicated by the large majority of consumers in Groups II and III having chosen health as the most important information) has the strongest impact on WTP, even when it is not the first information provided.

Table 5. Change in WTP per Information Sequence and Group

	Group I	Group II	Group III
$WTP_{2.} - \text{WTP}_{1.}$	-0.154	-0.152	-0.151
$WTP_{3.} - \text{WTP}_{2.}$	-0.030	-0.119	-0.089
$WTP_{4.} - \text{WTP}_{3.}$	-0.019	-0.001	-0.023
$WTP_{5.} - \text{WTP}_{4.}$	-0.057	-0.011	-0.010

Conclusion

Results show that the value of information for consumers is affected by its access conditions and its precise contents. The message that is considered most important clearly overrides the impact of other pieces of information. When consumers are able to choose the information they consider most important first, the effect of this information is largest. This is of particular importance in a market with different kinds of uncertain scientific knowledge and information available, as it is the case for food nanotechnology.

Results show that health information clearly decreases WTP, while societal and environmental information only slightly decrease WTP. The possibility for firms to use advertising of environmental attributes for product promotion in this context is doubtful, despite potential benefits from food-packaging improvements of nanotechnological innovations. Consumer benefit very much depends on assuring consumers of the sanitary safety of nanotechnology food products. Food safety agencies should focus on studies on safety, guaranteeing a higher level of certainty. Results further show that short and simple information on nanofood (before the elicitation of WTP_2) could scare some consumers. The absence of significant impacts when introducing a discussion with regard to the choice of information shows that group-based approaches such as short focus-group discussions may add little value to product evaluation exercises by consumers.

One limitation of our methodology is the hypothetical elicitation of WTP. One interesting extension would be an *ex-post* examination of consumers' reactions to the introduction of food nanotechnologies. This would strengthen the robustness of our *ex ante* results (that is, results determined before the real introduction of food nanotechnolgies).

Another extension could be to think about the priority given to health and safety information compared to environmental and societal information. This raises the question of validity of studies focusing only on WTP for a better environment. A bias may possibly come from the absence of health dimensions that would in reality eclipse other characteristics. To investigate this issue, one approach could consist in running an experiment on an environmental dimension with health consequences and another environmental dimension without health consequences. Beyond these questions, our paper shows the importance of health issues and related uncertainties in the introduction of new products.

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