

# Heterogeneous Consumer Preferences for Nanotechnology and Genetic-modification Technology in Food Products

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## Abstract

*This study investigates heterogeneous consumer preferences for nanofood and genetically-modified (GM) food and the associated benefits using the results of choice experiments with 1,117 US consumers. We employ a latent class logit model to capture the heterogeneity in consumer preferences by identifying consumer segments. Our results show that nano-food evokes fewer negative reactions compared with GM food. We identify four consumer groups: 'Price Oriented/Technology Adopters', 'Technology Averse', 'Benefit Oriented', and 'New Technology Rejecters'. Each consumer group has a distinctive demographic background, which generates deeper insights into the diversified public acceptance of nano-food and GM food. Our results have policy implications for the adoption of new food technologies.*

**Keywords:** choice experiment; genetic-modification; latent class models; Nanotechnology.

**JEL classifications:** D12, Q13, Q18.

## 1. Introduction

The application of novel technologies to food, such as biotechnology and nanotechnology, continues to grow rapidly. Food with genetically modified ingredients

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currently constitutes a large portion of domestic food supply in the US, including an estimated 70% of processed foods (Hallman *et al.*, 2003). While the use of nanotechnology is presently limited in the food market, the prospect for its growth in the food supply and economy is significant. Numerous companies are pursuing food nanotechnology applications for release to both domestic and international consumer markets in the near and long term, with a predicted rise in total market value to US\$ 20 billion by 2015 (Groves and Titoria, 2009). Given the strong prevalence and interest in food produced using genetic modification (GM food) and nanotechnology (nano-food), it is important to understand consumer perceptions of the benefits and risks, as well as to understand how product acceptance is affected by price, labeling, and these risks and benefits.

Potential benefits and risks of both technologies have been raised in the academic literature and debated in the media. Gaps in potential risk studies on nano-food and GM food products have been voiced as one major type of concern (e.g. Besley *et al.*, 2008; Bouwmeester *et al.*, 2009). Various organisations and groups have also called for mandatory labeling of GM and nano-food products (Caswell, 1998; Teisl *et al.*, 2003; Kalaitzandonakes *et al.*, 2007; Monica, 2008), which focuses public attention on previous evidence (Teisl *et al.*, 2003; Pidgeon and Rogers-Hayden, 2007; Burri and Bellucci, 2008). However, more recently, anti-technology movements in the food sector have been questioned and challenged. For example, the mandatory GM labeling failed to pass the California and Washington senates.

It is also widely acknowledged that both GM and nano-foods can provide significant enhancements to nutrition, taste, safety and protection of the environment. Despite the anticipated benefits such as pesticide reduction (Phipps and Park, 2002), taste enhancement (Rojas-Méndez *et al.*, 2012) and shelf-life extension (Rojas-Méndez *et al.*, 2012), the application of GM technology to food has generated widespread public controversy. Many studies investigating consumer preference for GM foods indicate that GM foods are generally not favoured by consumers in the United States, Japan, United Kingdom, Argentina, Germany, Sweden and France (Magnusson and Hursti, 2002; Mucci and Hough, 2004; Lusk *et al.*, 2005; Christoph *et al.*, 2008). Some of the reasons behind the opposition include people's previous knowledge of GM technology, risk perception of and safety concerns about the technology (Lusk *et al.*, 2005; Christoph *et al.*, 2007), distrust in government management of the technology and media coverage of the potential risks (Costa-Font *et al.*, 2008), and cultural world views (Finucane and Holup, 2005). In contrast, compared to consumers from developed countries, consumers from less developed countries tend to have more positive attitudes toward GM foods (Huang *et al.*, 2006; Krishna and Qaum, 2008) due to perceived benefits to food security and increased production (Curtis *et al.*, 2004). Regardless, across studies and countries, consumers are generally willing to pay a premium for foods free of GM ingredients (of about 10–50%) while the magnitude of consumers' discount for GM foods depends upon the type of genetic modification, the type of food product, and how the genetic modification alters the final product (Colson and Rousu, 2013).

Multiple studies have also been conducted to evaluate the relationship between individual characteristics (socio-economics, demographics and religious beliefs) and attitudes toward GM foods. Some of the major factors that affect consumers' preferences for GM foods are education (Lusk *et al.*, 2004), gender (Moerbeek and Casimir, 2005), age (Hossain *et al.*, 2003) and income (Hu *et al.*, 2005). Religious beliefs are

found to be irrelevant or unimportant factors influencing consumer attitudes toward GM foods (Hossain *et al.*, 2002, 2003; Hossain and Onyango, 2004).

Nanotechnology applications to food products, though less known by the public, are also expected to bring a range of benefits, including improved taste, less fat, enhanced absorption of nutrients, improved food safety and traceability (Kuzma and VerHage, 2006; Chaudhry *et al.*, 2008, 2010; Kuzma *et al.*, 2008). A major focus of nano-food is the development of nanostructured food ingredients and nano-engineered particulate additives and delivery systems for nutrients and supplements (Sozer and Kokini, 2009), such as low-fat nanostructure mayonnaise (Lyons, 2010), and self-assembled nutritional nanotubes (Graveland-Bikker and de Kruif, 2006; Neethirajan and Jayas, 2011). Nanotechnology could also offer environmental benefits, especially in the field of 'smart' agricultural production. Some nano-seed varieties with built-in pesticides that release under certain environmental conditions could make more efficient use of pesticides (Kuzma and VerHage, 2006; Scrinis and Lyons, 2007).

While there are many studies on consumer preferences for GM foods, similar studies for nano-foods are lacking. In past nanotechnology and public perception research, nano-food products were not the focal point (e.g. Burri and Bellucci, 2008; Kahan *et al.*, 2009). However, a few studies focusing on public perceptions about nano-foods have taken place in recent years. Siegrist *et al.* (2007) created a hypothetical model where Swiss consumer's social trust (in nanotechnology producers) impacted perceptions of nanotechnology food information, which in turn fed into consumer benefit and risk perceptions, ultimately determining consumers' willingness to buy a given nanotechnology food product. Another Swiss consumer study found consumer willingness-to-buy is lower for hypothetical products with an added health benefit resulting from nanomaterial additives compared to natural additives, though higher compared to products with no additional benefit at all (Siegrist *et al.*, 2009). Marette *et al.* (2009) utilised choice experiments to evaluate the impact of environmental, societal and health information on German consumers' willingness to pay (WTP) for orange juice with nano-ingredients. The results showed that health information about nanotechnology significantly decreases consumers' WTP, while societal and environmental information does not have significant impacts. Vandermoere *et al.* (2011) found that consumers' knowledge about nanotechnology significantly influences their attitudes toward nano-food packaging, but does not significantly affect their attitudes towards nano-food. More recently, Bieberstein *et al.* (2013) evaluated French and German consumers' WTP for nano-food and concluded that consumers in both countries are reluctant to accept nano-food, and more detailed information on nanotechnology further decreases consumer WTP. A recent study by Brown and Kuzma (2013) using focus group research found that people tend to prefer applications of nano-food that fill needs of nutrition or safety, and they are more comfortable with nanomaterials in packaging than within the food itself (Brown and Kuzma, 2013).

Although GM and nano-foods are notably similar as applications of novel broad-based technologies to food in uncertain public knowledge contexts, some notable differences exist. GM foods involve primarily 'genetic' changes to ingredients whereas nano-food applications usually apply 'chemical' or structural changes. GM foods are already prevalent on the market, while nano-foods are just emerging. GM foods have had high profile media and policy debates (e.g. California's recent labeling

proposition), whereas nano-foods have not. Consumers' conceptualisation of nano-technology in food may be more nuanced or differently developed than GM food. Furthermore, Priest *et al.* (2011) concluded that biotechnology is perceived differently than nanotechnology in part because of the 'biological' and 'material' differences: whereas biotechnology attitudes are polarised from the outset, nanotechnology does not seem to evoke such strong public reactions.

Given the mixture of similarities, contrasts, and differing market prevalence, we compare consumer preferences and WTP for GM food and nano-food in the context of types of benefits. Although there are many studies on consumer preferences for GM food and the literature on consumer preferences for nano-food is also growing, very few studies directly compare preferences for GM and nano-food in one experiment. Ours is one of the few studies that have jointly investigated US consumer preferences for nano-food and GM food in a single choice experiment, and by including both technologies in the same choice experiment we have accounted for the confounding factors that prevent comparison across different studies (Lusk *et al.*, 2005). Previous research by Zhou *et al.* (2013) and Zhou (2013) found that while consumers value non-GMO canola oil, they are willing to pay less for the non-GMO canola oil if it is produced from nanoscale-modified seeds or if the oil is packed in nanotechnology-enhanced packages. As mentioned above, it has been found that benefits do affect public perceptions of GM foods (Colson and Rousu, 2013) and nano-food (Siegrist *et al.*, 2009; Brown and Kuzma, 2013). Our study provides a direct comparison of the two technologies and of associated benefits, and further explores heterogeneity in consumer preference to better understand the range of consumer differences under a reasonable segmentation of latent groups. While previous studies have also discovered that public attitudes towards emerging technologies are not monolithic (e.g. Priest, 2006; Kahan *et al.*, 2009), ours is relatively novel in exploring this in the context of both GM and nano-foods amongst US consumers.

## 2. Methodology

### 2.1. Product attributes

The product we used to investigate consumer preference for nanotechnology and GM technology was rice. We chose rice because it is a product most people consume in a year, does not generally present food allergens, is modestly priced, and has been proposed for nutritional enhancement through genetic engineering (e.g. Golden Rice). In this study, the 'technology attributes' of rice tested were three types of production technology: rice enhanced with nanotechnology, GM or conventional breeding. The 'benefits' generated using the different production technologies were general benefits including enhanced nutrition, enhanced taste, enhanced food safety, less harmful impact on environment or no benefit. Following previous studies (Loureiro and Bugbee, 2005; Tonsor, 2011; Michaud *et al.*, 2013), we employed general benefits instead of specific benefits (e.g. 50% increase in Vitamin A) because this study aims to investigate which general benefits consumers prefer to acquire through GM or nanotechnology. Is it taste, nutrition, less harmful impact on the environment or food safety? This information could help the food industry determine which general benefits they should improve using the technologies and make the investments. The benefits were selected by reviewing the relevant

Table 1  
Choice experiment attribute and the corresponding attribute levels

Attribute	Level
The Production Technology used to produce the rice	Nanotechnology Genetic modification Conventional
The type of Benefit that could be attained by using the given technology	Enhanced nutrition Improved product taste Improved food safety of the rice Less harmful impact on the environment during production No additional benefit
Product Price for a 32 oz (2 lb) bag of long grain white rice	US\$ 3.75 US\$ 5.00

literature about both GM and nanotechnology and their applications in the food industry. The two ‘price’ choices were US\$ 3.50 and US\$ 5.00. The two price levels were selected by researching the rice prices in different stores. The attribute and the corresponding attribute levels are shown in Table 1.

## 2.2. Choice experiment

Choice experiments are widely used by researchers to investigate consumer preferences and WTP for goods (Lusk and Schroeder, 2004; Loureiro and Umberger, 2007; Yue and Tong, 2009). Choice experiments are based on random utility theory and Lancaster’s consumer demand theory (Lancaster, 1966), implying that consumers derive utility from attributes of a good rather than from the good itself. Choice experiments are composed of a combination of attributes, so they allow researchers to value various attributes simultaneously. Additionally, compared to experimental auctions, choice experiments typically ask people to choose between different products instead of asking people to name their own prices for products, which is similar to an actual purchasing situation (Lusk and Schroeder, 2004).

In this study, choice experiments were conducted to elicit consumer preference and WTP for the technology and benefit attributes of rice. Participants were presented with a series of choice scenarios regarding a 32 oz (2 lb) bag of long grain white rice, which consisted of varied combinations of the product attributes listed in Table 1. To reduce the cognitive burden on participants in the choice experiment, only two alternatives were included in each scenario along with an opt-out option indicating that neither of the two alternatives is preferred. Since it was not practical to ask each participant to choose from all possible scenarios, a fractional factorial design was developed to minimise scenario number and maximise profile variation. The fractional factorial design included the main effects of the technologies and the benefits and comprised a set of 16 scenarios. The clearly dominating alternatives were eliminated (Louviere *et al.*, 2000). The choice scenarios were designed using JMP<sup>®</sup> 8 software (SAS Institute Inc, Cary, NC). Before discrete choice questions, we also provided general information about two technologies to familiarise participants with the

Table 2  
Choice scenario question example

Option	A	B	C
Production technology	Nanotechnology	Genetic modification	Neither A nor B
Benefit	Less harmful impact on the environment	Enhanced nutrition	
Price	US\$ 3.75	US\$ 5.00	

technologies before they made their choices. An example choice scenario is provided in Table 2.

2.3. Sampling method

These data<sup>2</sup> were collected in August 2013 using online surveys from a representative US consumer sample provided by Qualtrics™, a professional survey company. Qualtrics™ panels have become increasingly popular for the assessment of consumer preference for different products in various countries. For example, Li *et al.* (2012) used a Qualtrics™ panel to sample consumers in China to estimate their WTP for luxury fashion brands related to their fashion lifestyle and perceived value. Saunders *et al.* (2013) surveyed 3,748 participants in three different countries by using Qualtrics™ panels to assess consumer attitudes towards and preferences for a number of food attributes and origins. To obtain a representative sample of rice consumers, we asked a screening question ‘have you purchased rice in the past year?’ at the start of the survey. Only the participants who answered ‘yes’ to this question completed our survey.

2.4. Econometric model

As consumers possess heterogeneous preferences, employing a model that allows evaluation and explanation of preference heterogeneity is appropriate (Lusk *et al.*, 2005). For choice experiment data, the mixed logit model (also known as random parameter logit model) is widely employed (Lusk *et al.*, 2005; Ouma *et al.*, 2007; Tonsor *et al.*, 2009; Zhou *et al.*, 2013), because it allows the taste parameters to vary randomly, so it does not need the independence of irrelevant alternatives assumption (Revelt and Train, 1998; McFadden and Train, 2000). However, while the mixed logit model allows continuous heterogeneity, it is not well suited for explaining sources of heterogeneity (Boxall and Adamowicz, 2002). A latent class model can better explain the sources of heterogeneity. The latent class model assumes that individuals can be intrinsically sorted into a number of latent classes, that each class is characterised by homogeneous preferences, and that the preferences are heterogeneous across classes. Therefore, in this study, we employed the latent class logit model to investigate consumer segmentations in terms of their preferences for food products produced with different technologies and with different benefits.

<sup>2</sup>IRB approval has been obtained from the university to conduct the surveys with US consumers.



The latent class logit model used in our study is described using equation (1):

$$U_{ijt} = \beta'_i x_{ijt} + \varepsilon_{ijt} \quad (1)$$

in which individual  $i$  ( $i = 1, 2, \dots, N$ ) selects alternative  $j$  with the preferred technology, benefit and price combination among a set of  $M$  alternatives ( $j = 1, 2, \dots, M$ ). The individual needs to make choices for  $t$  ( $t = 1, 2, \dots, W$ ) choice scenarios.  $x_{ijt}$  is a vector of observed variables that consist of certain technology, benefit and price levels, and  $\beta'_i$  is the individual-specific coefficient vector that is unobserved and varies within the population with the density function  $f(\beta|\theta)$ , where  $\theta$  is a vector of the true parameter of distribution for taste.  $\varepsilon_{ijt}$  is the random error term that is independently and identically distributed.

The latent class model simultaneously sorts individuals into a certain number of latent classes based on their choice of preferred attribute combinations, so members of each class have similar preferences for food technologies and benefits. In the latent class logit, the distribution  $f(\beta|\theta)$  is discrete with  $\beta$  as a finite set of distinct values (Train, 2009). Each individual is assigned to the latent class with the highest predicted likelihood of belonging. Specifically, the probability that individual  $i$  ( $i = 1, 2, \dots, N$ ) chooses option  $j$  ( $j = 1, 2, \dots, M$ ) in choice scenario  $t$  ( $t = 1, 2, \dots, W$ ), given that this individual belongs to latent class  $s$  ( $s = 1, 2, \dots, S$ ) is:

$$\Pr(ijt|s) = \prod_{t=1}^W \frac{e^{\beta_s x_{ijt}}}{\sum_j^M e^{\beta_s x_{ijt}}} \quad (2)$$

where  $x_{ijt}$  is a vector of observed attributes associated with alternative  $j$ , and  $\beta_s$  is a vector of class-specific utility parameters to capture heterogeneity in preferences across classes (Ouma *et al.*, 2007). Since the class membership status is unknown, the weight for latent class  $s$  is the population share of that class and is specified by a fractional multinomial logit. Let  $\pi_{si}(s)$  denotes the weight for class  $s$ .

$$\pi_{si}(s) = \frac{e^{\theta'_s m}}{1 + \sum_{s=1}^{S-1} e^{\theta'_s m_t}} \quad (3)$$

where  $m_t$  is a set of observable characteristics for class membership and  $\theta'_s$  is a vector for class membership model parameters.

### 3. Results and Discussions

A total of 1,145 online surveys were completed, 28 of which were discarded due to incomplete information. The socio-demographic characteristics of the sample respondents are summarised in Table 3. The average age of the sample is 48 years; the average education level is some college degree (associate degree included); and the average household income is about US\$ 50,000. Forty-nine percent of participants are male. In addition to the basic demographics, our study also requested information on participants' religious background. According to five religion-related questions, the average religious profile for the sampled participants is someone who attends religious service less often than once a month, considers themselves as a moderate person between liberal and conservative, views themselves as somewhat religious, makes daily life decisions guided by religion to a small extent, and views science and technology without too much influence by religiosity. The last column of Table 3 also shows the mean of age, income, gender, education

Table 3  
Explanation and statistics of demographics

Demographic characteristic	Explanation	Mean (SD)	US census
<i>Age</i>	Age of Respondents	47.86 (15.54)	45.16
<i>Education</i>	Highest educational level completed:	4.32 (1.26)	4.39
	1 Less than high school		
	2 Some high school		
	3 High school (includes GED)		
	4 Some college (includes associate degree)		
	5 College graduate (BS, BA, etc.)		
	6 Some graduate education		
	7 Graduate degree (MA, MS, PhD, JD, MD, etc.)		
<i>Income</i>	Total family income in 2012, before taxes and other deductions in US\$:	2.80 (1.36)	3.05
	1 Less than 25,000		
	2 25,000–50,000		
	3 50,000–75,000		
	4 75,000–100,000		
	5 100,000–150,000		
	6 More than 150,000		
<i>Gender</i>	0: Female; 1: Male	0.49 (0.50)	0.49
<i>Race</i>	0: Not Hispanic or Latino 1: Hispanic or Latino	0.07 (0.25)	0.17
<i>White</i>	0: Race identified not White; 1: Race identified as White	0.88 (0.32)	0.74
<i>Reliattend</i>	How often have you attended religious services in the past year:	5.19 (2.54)	–
	1 More than once a week		
	2 About once a week		
	3 2–3 times a month		
	4 About once a month		
	5 Less than once a month		
	6 Only on special holy days		
	7 About once a year		
	8 Have not attended		
<i>Religious</i>	How religious would you say you are:	2.36 (0.97)	–
	1 Very religious		
	2 Somewhat religious		
	3 Not too religious		
	4 Not religious at all		



Table 3  
(Continued)

Demographic characteristic	Explanation	Mean (SD)	US census
<i>Relidecision</i>	How much does religion guide the decisions you make on a daily basis:	3.62 (1.93)	–
	1 Not at all		
	2 Not too much		
	3 A little		
	4 Some		
	5 Mostly		
	6 A great deal		
	7 Completely		
<i>Reliview</i>	How much does religiosity affect your views relating to science and technology:	2.66 (1.75)	–
	1 Not at all		
	2 Not too much		
	3 A little		
	4 Some		
	5 Mostly		
	6 A great deal		
	7 Completely		
<i>Politcon</i>	How would you scale your level from ‘liberal’ to ‘conservative’:	3.05 (1.09)	
	1 Very liberal		
	2 Somewhat liberal		
	3 Moderate		
	4 Somewhat conservative		
	5 Very conservative		

and race of the US census data. Our sample is consistent with the US census (US Census Bureau, 2010) in terms of age (age group 15–83 years), gender, family income and education.

### 3.1. Consumer heterogeneity – estimation results of the latent class logit model

The estimation results of the latent class logit model are presented in Table 4, each group’s WTP values for the technologies and the benefits are presented in Table 5. Each group’s WTP values for the combinations of technology and attributes are reported in Table 6. To avoid confounding the ‘opt out’ impacts we used effect coding (Ouma *et al.*, 2007). The constant variable in the model represents ‘opt out’ option and it has ‘zero’ utility. Our results show that the coefficient for the constant variable (‘opt out’) in each latent class is significantly negative, which illustrates our participants have a strong negative preference for this option, implying

Table 4  
Maximum likelihood estimation results of the latent class logit model

Variables	Coefficient (Std. Err.)			
	Group 1: 'price oriented'	Group 2: 'technology averse'	Group 3: 'benefit oriented'	Group 4: 'new technology rejecters'
<i>Attribute coefficient</i>				
<i>Constant</i>	-11.76*** (0.52)	-2.84*** (0.34)	-3.52*** (0.18)	-2.23*** (0.47)
<i>Price</i>	-2.01*** (0.09)	-0.93*** (0.07)	-0.12*** (0.03)	-0.72*** (0.09)
<i>Nanotech</i>	-0.19** (0.06)	-0.65*** (0.05)	-0.12*** (0.02)	-2.44*** (0.07)
<i>GM</i>	-0.21*** (0.06)	-0.72*** (0.05)	-0.13*** (0.02)	-2.80*** (0.10)
<i>Nutrition</i>	0.84*** (0.10)	0.19*** (0.06)	0.63*** (0.04)	0.40*** (0.10)
<i>Safety</i>	0.44*** (0.11)	0.36*** (0.06)	0.73*** (0.04)	0.79*** (0.09)
<i>Environment</i>	0.09 (0.09)	0.10 (0.06)	0.50*** (0.04)	0.27*** (0.08)
<i>Taste</i>	0.66*** (0.09)	0.00 (0.06)	0.37*** (0.04)	0.40*** (0.10)
<i>Membership coefficient</i>				
<i>Age</i>	—	0.00 (0.01)	-0.01 (0.01)	0.01 (0.01)
<i>Education</i>	—	-0.17 (0.10)	-0.30*** (0.08)	-0.02 (0.08)
<i>Gender</i>	—	0.98*** (0.23)	0.40* (0.20)	0.97*** (0.21)
<i>Income</i>	—	-0.13 (0.09)	0.17* (0.08)	0.09 (0.08)
<i>Race</i>	—	0.47 (0.48)	0.60 (0.40)	-0.07 (0.48)
<i>White</i>	—	-0.32 (0.36)	-0.52 (0.31)	0.560 (0.40)
<i>Reliattend</i>	—	-0.09 (0.05)	-0.14** (0.05)	-0.05 (0.05)
<i>Religious</i>	—	0.29 (0.19)	0.22 (0.17)	0.55** (0.18)
<i>Relidecision</i>	—	0.04 (0.11)	0.13 (0.09)	0.23* (0.10)
<i>Reliview</i>	—	0.15 (0.09)	0.08 (0.08)	0.06 (0.08)
<i>Politcon</i>	—	-0.09 (0.11)	-0.34*** (0.09)	-0.15 (0.10)
<i>_cons</i>	—	0.23 (1.01)	2.78*** (0.85)	-2.62** (0.97)

Table 4  
(Continued)

Variables	Coefficient (Std. Err.)			
	Group 1: 'price oriented'	Group 2: 'technology averse'	Group 3: 'benefit oriented'	Group 4: 'new technology rejecters'
Frequency	197	192	450	278
Share	17.6%	17.2%	40.3%	24.9%

Notes: \*, \*\*, and \*\*\* denote significance at 5%, 1% and 0.1% levels, respectively.

that the respondents preferred to select the two choice options associated with a combination of technology and benefit rather than to 'opt out'. There are four latent classes defined based on the Bayesian Information Criterion or BIC (Boxall and Adamowicz, 2002). The BIC value of four-class model is lower than those of the one-class, two-class and three-class models. Additionally, the four-class model has the highest posterior prediction accuracy (96.5%), meaning that the model performs very well in distinguishing among different underlying preference patterns for the observed choice behaviour. We also included the socio-demographic variables in the latent class logit model.

Based on the coefficients and attribute/price ratios (WTP values) of technologies and benefits for each latent class defined, we named the four estimated latent classes as 'Price Oriented/Technology Adopters', 'Technology Averse', 'Benefit Oriented' and 'New Technology Rejecters', respectively.

Table 5  
WTP estimates for the four consumer segments

Attributes	WTP (\$/lb) (95% CI)			
	Group 1: 'Price Oriented'	Group 2: 'Technology Averse'	Group 3: 'Benefit Oriented'	Group 4: 'New Technology Rejecters'
<i>Nanotechnology</i>	−0.09** (−0.15, −0.03)	−0.70*** (−0.83, −0.58)	−0.94*** (−1.39, −0.48)	−3.39*** (−4.18, −2.60)
<i>GM</i>	−0.10*** (−0.16, −0.05)	−0.78*** (−0.92, −0.64)	−1.06*** (−1.53, −0.58)	−3.90*** (−4.79, −3.00)
<i>Nutrition</i>	0.42*** (0.34, 0.50)	0.21*** (0.09, 0.33)	5.16*** (3.00, 7.31)	0.56*** (0.30, 0.82)
<i>Safety</i>	0.22*** (0.12, 0.32)	0.39*** (0.27, 0.52)	5.96*** (3.54, 8.39)	1.10*** (0.82, 1.38)
<i>Environment</i>	—	—	4.08*** (2.43, 5.74)	0.37*** (0.17, 0.56)
<i>Taste</i>	0.33*** (0.25, 0.41)	—	2.99*** (1.73, 4.25)	0.56*** (0.27, 0.84)

Notes: \*, \*\*, and \*\*\* denote significance at the 0.05, 0.01 and 0.001 levels, respectively. "—" indicates that the estimated coefficient is not statistically significant, and the WTP value is not calculated.

Table 6  
WTP for the combinations of technologies and benefits for the four consumer segments

WTP(\$/lb) (95% CI)	Group 1: 'price oriented'		Group 2: 'technology averse'		Group 3: 'benefit oriented'		Group 4: 'new technology rejecters'	
	Nano- technology	GM	Nano- Technology	GM	Nano- technology	GM	Nano- technology	GM
<i>Nutrition</i>	0.33*** (0.25, 0.40)	0.32*** (0.24, 0.39)	-0.49*** (-0.65, -0.34)	-0.57*** (-0.73, -0.41)	4.22*** (2.37, 6.08)	4.10*** (2.27, 5.94)	-2.83*** (-3.59, -2.06)	-3.33*** (-4.17, -2.50)
<i>Safety</i>	0.12** (0.04, 0.21)	0.11** (0.03, 0.20)	-0.31*** (-0.46, -0.16)	-0.38*** (-0.53, -0.24)	5.03*** (2.91, 7.15)	4.91*** (2.82, 6.99)	-2.29*** (-2.93, -1.64)	-2.79*** (-3.54, -2.05)
<i>Environment</i>	-	-	-0.60*** (-0.77, -0.42)	-0.67*** (-0.85, -0.49)	3.15*** (1.78, 4.52)	3.03*** (1.68, 4.38)	-3.02*** (-3.82, -2.23)	-3.53*** (-4.42, -2.64)
<i>Taste</i>	0.23*** (0.17, 0.30)	0.22*** (0.15, 0.30)	-0.70*** (-0.88, -0.53)	-0.78*** (-0.96, -0.60)	2.05*** (1.07, 3.03)	1.93*** (0.97, 2.89)	-2.83*** (-3.57, -2.10)	-3.34*** (-4.14, -2.54)

**Notes:** \*, \*\*, and \*\*\* denote significance at the 0.05, 0.01 and 0.001 levels, respectively. “-” indicates that the estimated coefficient is not statistically significant, and the WTP value is not calculated.

Group 1 is 'Price Oriented/Technology Adopters' group, which accounts for 17.64% of the sample. In this group, the absolute value of the coefficient for price (2.007) is the highest among all parameters, which means participants in group 1 are the most sensitive to the change in price. The 'Price Oriented/Technology Adopters' group discounts GM slightly more than nanotechnology. For this group, the enhanced nutrition is the most preferred benefit followed by improved taste and safety. The coefficient for less harmful impact on environment is not significant.

This group's WTP values for different technologies are the lowest and closest to zero among the four groups. Participants in this group discount GM and nanotechnology by only US\$ 0.10/lb and US\$ 0.09/lb, respectively, and they are willing to pay a premium of US\$ 0.42/lb for enhanced nutrition, US\$ 0.33/lb for improved taste and US\$ 0.22/lb for improved safety. From Table 6 we can see that the combination of nanotechnology and a benefit, and the combination of GM and a benefit have similar WTP values for 'Price Oriented/Technology Adopters'. Participants in this group are willing to pay the highest premium for nutrition enhancement with a premium of US\$ 0.33/lb for nanotechnology, and a premium of US\$ 0.32/lb for GM. Taste improvement has a US\$ 0.23/lb WTP premium when nanotechnology is applied and a premium of US\$ 0.22/lb when GM is used. The price premiums for improved food safety are US\$ 0.12/lb for nanotechnology and US\$ 0.11/lb for GM, respectively. This group is not willing to pay for either of the technologies to reduce harmful impact on the environment. Because this group's WTP results for the combinations of technologies and benefits are either slightly positive (but statistically significant) or statistically insignificant, we also call this group of participants the 'Technology Adopters'.

Group 2, the 'Technology Averse' group, consists of 192 participants (17.2% of the sample). The most obvious feature for this group is that the coefficients for nanotechnology and GM are significantly negative, whereas the coefficients for benefit attributes are comparatively less positively significant. In this group, participants are strongly against the use of GM with an estimated coefficient of  $-0.72$ , compared with the coefficient of  $-0.65$  for nanotechnology. The negative coefficients for the two technologies dominate the positive coefficients of the four benefits (the only two statistically significant coefficient values for the benefits are 0.36 for improved safety and 0.19 for enhanced nutrition).

Participants in the 'Technology Averse' group discount GM and nanotechnology by US\$ 0.78/lb and US\$ 0.70/lb, respectively. They are willing to pay the premiums of US\$ 0.39/lb and US\$ 0.21/lb for improved safety and nutrition, respectively. Overall, 'Technology Averse' participants discount the combinations of GM and benefits more than the combinations of nanotechnology and benefits. For the GM application in food products, 'Technology Averse' participants discount taste improvement the most ( $-\text{US\$ } 0.78/\text{lb}$ ), followed by less harmful impact on the environment ( $-\text{US\$ } 0.67/\text{lb}$ ), nutrition enhancement ( $-\text{US\$ } 0.57/\text{lb}$ ), and safety improvement ( $-\text{US\$ } 0.38/\text{lb}$ ). The same preference ranking applies to the WTP results for the combinations of nanotechnology and benefits. 'Technology Averse' participants discount the use of nanotechnology to improve taste the most ( $-\text{US\$ } 0.70/\text{lb}$ ), followed by less harmful impact on the environment ( $-\text{US\$ } 0.60/\text{lb}$ ), improved nutrition ( $-\text{US\$ } 0.49/\text{lb}$ ) and improved safety ( $-\text{US\$ } 0.31/\text{lb}$ ).

Group 3, the 'Benefit Oriented' group, is the majority segment that consists of 40.3% of total participants. This group is called 'Benefit Oriented' as the coefficients of the benefit attributes are significantly positive and dominate the negative coefficients of the technologies. This indicates that participants in this group do not care

about what technology is adopted during production as long as certain benefits can be brought by the technology. Within the four benefits, this group values safety the most with a coefficient of 0.73, followed by nutrition enhancement (0.63), less harmful impact on the environment ranks the third with a coefficient of 0.50, and improved taste is the least preferred benefit (0.37).

As a result, 'Benefit Oriented' participants are willing to pay significantly higher premiums for the benefits compared to their discounts for the two technologies. They are willing to pay US\$ 5.96/lb for enhanced safety, US\$ 5.16/lb for enhanced nutrition, US\$ 4.08/lb for less harmful impact on environment and US\$ 2.99/lb for improved taste. In addition, all the WTP values for the combinations of the technologies and the benefits are significantly positive at the 0.001 level. The results indicate that about 40% of participants prefer the use of nanotechnology and GM to improve benefits for food products. Using nanotechnology to improve food safety is preferred the most (US\$ 5.03/lb), and employing GM to improve taste is preferred the least (US\$ 1.93/lb).

Group 4, 'New Technology Rejecters', has 278 participants (24.9% of the total sample). Based on the estimation results of the latent class logit model, the coefficients of nanotechnology (−2.44) and GM (−2.80) strongly dominate the coefficients of price (−0.72) and benefits (ranging from 0.27 to 0.79). Participants in this group reject nanotechnology or GM regardless of the associated benefits and prices whenever there is a conventional option.

'New Technology Rejecters' discount GM and nanotechnology by −US\$ 3.39/lb and −US\$ 3.90/lb, respectively and the highest price premium they are willing to pay is US\$ 1.10/lb for improved food safety. All technology and benefit combinations are significantly discounted from −US\$ 3.53/lb (GM with less harmful impact to environment) to −US\$ 2.29/lb (nanotechnology with enhanced food safety).

The membership coefficients show some of the demographic variables such as education, gender, income for groups 2–4 significantly differ from those of group 1. To further examine the detailed socio-demographic backgrounds of the four groups and test if the four groups' socio-demographic backgrounds are significantly different from each other, we employed ANOVA and MANOVA tests.

### 3.2. Socio-demographic profile, religious and political attitudes of the groups

The mean statistics of each group's socio-demographics and religious attitudes are provided in Table 7. To see if these differentiated groups differ significantly in their socio-demographic background, MANOVA and ANOVA were employed. The *P*-value of the MANOVA when including all variables is 0.0001, so the null hypothesis that the mean vectors for demographic and religious attitude variables are the same across the groups is rejected at the 0.01% level. For the socio-demographic background variables, the ANOVA tests show that the four latent classes differ significantly ( $P < 0.01$ ) in age, income, education, gender, race, frequency of attending religious activities, and liberal-conservative level.

Figure 1 summarises the major characteristics of the four latent classes.

'New Technology Rejecters' are the oldest with an average age of 50 years, followed by the 'Technology Adverse' group. 'Benefit Oriented' consumers are the youngest with an average age of 45 years. Previous studies have suggested that older participants are more likely to know about and value traditional food (Stewart, 2000; Guerrero *et al.*, 2010). They may also be less familiar with and resistant to new



Table 7  
Socio-demographics for the four consumer segments

<i>Demo</i>	Group 1: 'price oriented'/ 'technology adopters'		Group 2: 'technology averse'		Group 3: 'benefit oriented'		Group 4: 'new technology rejecters'		ANOVA
	Mean	Std dev	Mean	Std dev	Mean	Std dev	Mean	Std dev	
<i>Age</i>	48.89	13.60	48.65	16.07	45.59	16.82	50.25	13.81	0.0005
<i>Income</i>	2.80	1.37	2.42	1.27	2.92	1.42	2.88	1.27	0.0003
<i>Education</i>	4.47	1.27	4.16	1.24	4.20	1.27	4.49	1.21	0.0016
<i>Gender</i>	0.35	0.48	0.60	0.49	0.46	0.50	0.57	0.50	0.0001
<i>Race</i>	0.05	0.21	0.07	0.25	0.09	0.29	0.04	0.20	0.0285
<i>White</i>	0.91	0.28	0.88	0.33	0.83	0.38	0.95	0.23	0.0118
<i>Religious</i>	2.41	0.99	2.32	1.00	2.30	0.92	2.45	1.01	0.1848
<i>Reliattend</i>	5.68	2.41	5.15	2.62	4.85	2.51	5.42	2.55	0.0005
<i>Reliview</i>	2.41	1.68	2.83	1.88	2.74	1.74	2.60	1.69	0.0688
<i>Relidecision</i>	3.34	1.88	3.69	2.05	3.70	1.86	3.66	1.98	0.1384
<i>Politcon</i>	3.19	1.11	3.14	0.98	2.91	1.09	3.08	1.11	0.0057
Frequency	197		192		450		278		MANOVA
Share	17.64%		17.19%		40.29%		24.89%		0.0001

Group 1: 17.64% 'Price Oriented'	Group 2: 17.19% 'Technology Averse'	Group 3: 40.29% 'Benefit Oriented'	Group 4: 24.89% 'New Technology Rejecters'
<ul style="list-style-type: none"> <li>Extremely sensitive to price change.</li> <li>Generally adopts technology use with added benefits</li> <li>More male</li> <li>Attend fewer religious services</li> <li>More conservative</li> </ul>	<ul style="list-style-type: none"> <li>Discount the use of technology with any associated benefit.</li> <li>More female</li> <li>Less income</li> <li>Lower education level</li> </ul>	<ul style="list-style-type: none"> <li>Support the use of nanotechnology and GM to bring benefits.</li> <li>More minorities</li> <li>Younger</li> <li>Attend more religious services</li> <li>More liberal</li> </ul>	<ul style="list-style-type: none"> <li>Reject all technology applied to food products outright regardless of benefits.</li> <li>Older</li> <li>More female</li> <li>More white</li> <li>More conservative</li> </ul>

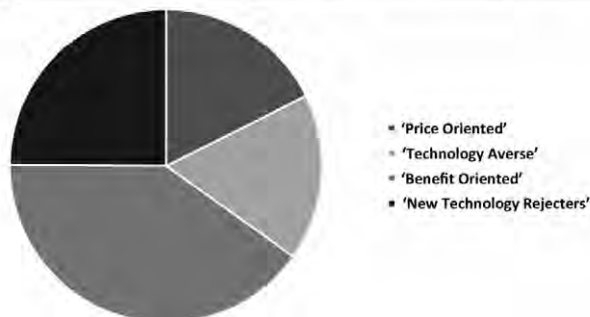


Figure 1. Consumer groups by preference and character

technologies, which is consistent with their more conservative tendencies (Slovic, 1987). Or it could be they are more aware of the downsides of technological innovation. More research is needed to investigate these age-related effects.

The 'Technology Averse' group has the lowest income level while participants in the other three groups have relatively similar income levels. Participants in the 'Benefit Oriented' and 'Technology Averse' groups have relatively lower education levels while participants in the other two groups have higher education levels. The 'Benefit Oriented' group participants may not be as aware of the possible negative consequences brought by the two technologies in comparison to the 'New Technology Rejecters', they are the youngest among the four groups, have the lowest percentage of Caucasians, attend religious activities the most often and consider themselves more liberal (*Politcon*).

The 'Price Oriented/Technology Adopters' group has the lowest percentage of females while 'New Technology Rejecters' and 'Technology Adverse' groups have significantly more female members, which suggests that the technologies are less acceptable to female participants. This is supported by previous research on risk perception and technology acceptance (Williams and James, 2001; Baker and Burnham, 2001; Cox *et al.*, 2007; Kahan *et al.*, 2007). The 'Price Oriented/Technology Adopters' also tend to attend fewer religious events.

In looking at the political views of the consumers, it is interesting to note the dichotomy between the two meta-groups identifying as more liberal ('Benefits Oriented') and those as more conservative ('New Technology Rejecters', 'Technology Averse' and 'Price Orientation/Technology Adopters'). Perhaps this could be explained by different factions of conservative people rejecting the technology outright for moral reasons (consistent with the 'Rejecters'), or alternatively accepting the technology for economic development and free-market reasons (consistent with the 'Price Orientation').

Finally, religious background may not necessarily affect a consumer's choice of food products produced using certain production technologies, as the two variables of how religion affects views of science and technology, and decisions about them (*Reli-view* and *Relidecision*) were not significant. This is consistent with previous findings that religiosity does not affect people's attitudes toward nanotechnology (Hossain *et al.*, 2002, 2003; Hossain and Onyango, 2004; Vandermoere *et al.*, 2010). However, the correlation between the groups and attending religious services (*Reliattend*) is interesting with 'Benefits Orientation' attending services the most.

#### 4. Conclusions and Policy Implications

Our study is one of the few studies that has investigated US consumer preferences for nano-food using choice experiments (Zhou, 2013; Zhou *et al.*, 2013). We find that GM is less acceptable than nanotechnology across all groups of participants and benefits. Safety benefits were most accepted, followed by nutrition, and then taste and the environment. Regardless, neither GM nor nano-foods are popular with consumers taken as a whole.

In previous work using focus groups, it was suggested that US consumers were more willing to accept nano-food products for nutrition or safety benefits (Brown and Kuzma, 2013). Our choice experiment confirms this finding, though consumers are heterogeneous in their preferences, splitting into four distinct groups. Brown and Kuzma (2013) showed consumers felt most positively about nano-foods that could be

beneficial in helping the poor or alleviating food insecurity. This view is consistent with consumers in group 3 'Benefits Orientation', who also attended more religious services, were more racially diverse, and were more liberal. This group does not reject the technologies outright due to risk. It is also noteworthy that this group was the largest amongst our participants (over 40% of participants). Thus, a key conclusion is that a sizeable proportion of people make nuanced choices about technology, and their minds are not made up about all applications of it. They are sceptical about the technologies unless the benefits of technology are worthwhile for the populace whom need or value it the most.

In contrast, 'Price Oriented' (17.6%) tended to be more male, more educated, and more conservative politically than other groups. This group did not attend religious services as often as the others. Interestingly, this group favoured individual benefits of GM taste and nutrition and nano-food taste and nutrition over safety, although price appears to dominate this group's decision making.

Group 2: 'Technology Adverse' (17.2%) and Group 4: 'New Technology Rejecters' (24.9%) were both more likely to be female, and while technology was resisted by both groups, participants in group 4 entirely avoided the two technologies when possible. Group 4 was also older, more white, attended fewer religious services, and was more conservative. These results are congruent with previous classes of attitudes towards new technologies.

Other studies have revealed groups with differing attitudes toward nanotechnology under the cultural cognition hypothesis (Kahan *et al.*, 2009) and toward technology more generally (Priest, 2006). There are some overlaps between our groups and these previous studies. For example, Priest (2006) identifies a group that makes decisions about emerging technologies based on risks and benefits ('democratic pragmatists'), which bears some similarities to our 'Benefit Oriented' group. Kahan *et al.* (2009) and Baker and Burnham (2001) found a significant segment of consumers strongly preferred a low-priced product (the same as our 'Price Oriented' group). Baker and Burnham (2001) further confirmed a group of 'Safety Seekers' who always sought to avoid cornflakes with GMO content, which resembles our 'Technology Averse' and 'New Technology Rejecter' groups.

From a policy perspective, our results suggest that the majority of US consumers will not reject these technologies outright, but base their decisions on a complex calculus of benefits, risks, technological comfort and safety. However, we do find a group of people (approximately 25% of the population) who oppose the application of nanotechnology or GM in the production of rice regardless of price level and corresponding benefits. This is consistent with a growing social movement in the US towards 'natural foods' (Group 4: 'New Technology Rejecters').

Wise policy choices and product development strategies might be to allow the 'New Technology Rejecters' group (Group 4) to make their own decisions by labeling nano-foods or GM foods either through voluntary industry initiatives or mandatory government initiatives, while making sure that nano-foods and GM foods provide benefits in safety and nutrition through industry product developments or government policy incentives to satisfy the desires of other groups (Group 3). For the food industry, claims of increasing food quality, and safety through technology should be verified for increasing acceptance by the majority of consumers who are somewhat open to technological advances (Groups 2 and 3), while keeping prices reasonable for those who are eager to adopt technologies (Group 1) and allowing those who reject technology to choose (Group 4).

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