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RESEARCH PAPER

# Investigating factors influencing consumer willingness to buy GM food and nano-food

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**Abstract** Emerging technologies applied to food products often evoke controversy about their safety and whether to label foods resulting from their use. As such, it is important to understand the factors that influence consumer desires for labeling and their willingness-to-buy (WTB) these food products. Using data from a national survey with US consumers, this study employs structural equation modeling to explore relationships between potential influences such as trust in government to manage technologies, views on restrictive government policies, perceptions about risks and benefits, and preferences for labeling on consumer's WTB genetically modified (GM) and nano-food products. Some interesting similarities and differences between GM- and nano-food emerged. For both technologies, trust in governing agencies to manage technologies did not influence labeling preferences, but it did influence attitudes about the food technologies themselves. Attitudes toward the two technologies, as measured by risk–benefit comparisons and comfort with consumption, also greatly influenced views of government restrictive policies, labeling preferences, and WTB GM or nano-food products. For differences, labeling preferences were found to influence WTB nano-foods, but not WTB GM foods. Gender and religiosity also had varying effects on WTB and labeling preferences: while gender and religiosity influenced labeling preferences and WTB for GM foods, they did not have a significant influence for nano-foods. We propose some reasons for these differences, such as greater media attention and other heuristics such as value-based concerns about "modifying life" with GM foods. The results of this study can help to inform policies and communication about the application of these new technologies in food products.

**Keywords** GM · Nanotechnology · Willingness to buy · Structural equation modeling · Food · Labelling

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## Introduction

There has been considerable growth in the application of novel food technologies including biotechnology and nanotechnology in recent years. According to USDA, 95 % of sugar beets, 93 % of soy, and 88 % of corn produced in the US are GM varieties (United States Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) 2012), and an estimated 75 % of processed foods contain genetically modified ingredients (Hallman 2012). The use of nanotechnology in the food industry (nano-food) is not as prevalent as GM food technologies, but is developing rapidly especially in use of nanomaterials in food packaging (Zhou 2013). Several food packaging products and dietary supplements, as well as a few food ingredients, containing engineered nanomaterials are already on the market (Project on Emerging Nanotechnologies 2014). Nanotechnology is projected to have an impact measured at least $1 trillion across the globe by 2020, and require at least 6 million workers by the end of decade (Roco et al. 2010). Despite this growth in both GM and nano-food products, public understanding is relatively low. Only 37 % of Americans are aware that GM food products are currently on shelves (IFIC 2014). Researchers have reported that current media information about nano-foods is severely limited (Dudo et al. 2011) and that public awareness is low with 62 % of Americans hearing only the term or nothing at all about nanotechnology (Harris 2012).

While these technologies are being developed to promote expected benefits in food including improved nutritional value, abundance, safety, and environmental protection, some researchers and organizations have noted concerns about safety, especially in light of the difficulties of testing the effects of GM and nano-food products on human health and the environment over long periods of time, at low levels of exposure, and under real-world risk conditions (Besley et al. 2008; Bouwmeester et al. 2009; NRC 2004, 2009). Various organizations and groups have called for mandatory labeling of GM and nano-food products (Caswell 1998; Teisl et al. 2003; Kalaitzandonakes et al. 2007; Monica Jr. 2008). In the United States, a majority of consumers want GM foods labeled when asked in public opinion polls, with most of these polls showing over 90 % of people in favor of GM food labeling (e.g., Kopicki 2013; Center for Food Safety 2014). Many studies have also found that consumers are willing to pay (WTP) a premium for GM food labeling or to avoid GM foods (reviewed in Colson and Rousu 2013). In a recent study using choice experiments, we found that US consumers are willing to pay more to avoid both GM and nano-foods, with a higher premium to avoid GM foods than nano-foods (Yue et al. 2014). The political context for GM food labeling in the United States is becoming more and more contentious as state mandatory labeling bills are proposed, publicly challenged, and fiercely opposed by agri-business companies (Allen and Cummins 2012). Despite the prominent expressed desires for labeling in public opinion polls, GM food labeling initiatives in California or Washington were not successful. This could be due to a variety of factors including voter turnout and exposure to advertising. Colson and Rousu (2013) summarize that support for the CA labeling of GM foods went from over 60–40 % as the television ad campaigns increased. However, other bills for mandatory labeling have been passed in Vermont, Connecticut, and Maine (Ford and Ferrigno 2014).

Various studies of public perceptions and consumer preferences concerning GM foods have demonstrated that consumers are reticent of GM food products and are willing to pay a premium to label or avoid them. Two recent review articles summarize studies. Frewer et al. (2013) find that there are differences in consumer acceptance of plant versus animal GM food, with acceptance of plant foods higher, and in risk perception among EU and US consumers, with EU consumers rating risks higher (Frewer et al. 2013). In a meta-analysis of economic studies, consumers were found to be 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). For instance, Huffman et al. (2003) conducted a choice experiment and found that the US consumers were willing to pay an average of 14 % more for similar food products that do not contain GM ingredients. This effect was strengthened for respondents who had previous knowledge of GM food technologies and the experimental manipulation of information (pro-GM, anti-GM, and balanced) further influenced WTP.

While studies of consumer preference for GM foods are somewhat abundant, there are fewer similar studies on nano-foods, and most have been conducted in Europe. A Swiss consumer study found consumer willingness to buy (WTB) was 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). Of note, WTB has been used as a measure of purchase intention, while WTP has been treated as an estimate of monetary value associated with desires to purchase or avoid food products. Marette et al. (2009) utilized choice experiments to evaluate the impact of environmental, societal, and health information on Germany consumers' WTP for orange juice with nano-ingredients. The results showed that health information about nanotechnology significantly decreases consumers WTP, while societal and environmental information do not have significant impacts. Vandermoere et al. (2011) indicated that consumers' knowledge about nanotechnology significantly influences their attitudes toward nano-food packaging, but it does not significantly affect their attitudes toward nano-food. More recently, Bieberstein et al. (2013) evaluated French and Germany 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 focus group study from the US on nano-food reports findings that consumers desire nano-food labeling, but are not strictly opposed to all forms of nano-food technologies (Brown and Kuzma 2013). They found that consumers preferred nanomaterials when used in food packaging over use of nanomaterials as food ingredients and when used for improving food safety and nutritional content over other types of benefit. In general, factors affecting consumer acceptance of nano-foods seem to be dynamic, complex, interactive, and interdependent, including trust, risks and benefits, levels of information, price, and cultural viewpoint (Yawson and Kuzma 2010).

Trust seems to be an important factor in emerging technologies and food acceptance, although results are mixed. Some researchers suggest that public attitudes toward emerging technologies are primarily driven by trust in regulating agencies of the technology, while alternative views posit that trust is a consequence and not a cause of such attitudes (Frewer et al. 2003; McGuire 1969). One experimental study concluded that trust in GM food information providers "appeared to be driven by people's attitudes to genetically modified foods, rather than trust influencing the way that people reacted to the information portrayed about GM foods" (Frewer et al. 2003). Their study supported the claim that trust in regulating agencies is not driven by risk and benefit attitudes but that attitudes inform perceptions of the motivating factors regulating agencies have in providing information to the public about GM foods. For nanotechnology and nano-foods, 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' WTB a given nanotechnology food product. Social trust in producers had a positive WTB impact, while perceived benefits had more of an effect than perceived risks. Contrastingly, in a different study, perceived risks of different food processing technologies, such as GM and irradiation, were the most important variables in deciding consumer interest in using food processed with those technologies (Cardello et al. 2007).

Conceptualization of nanotechnology in food may be more nuanced or differently developed than equivalent conceptualizations of GM food. Our desire in the current study was to test some of the factors found in the literature and compare GM to nano-food in the same study. GM and nano-foods are notably similar as applications of novel broad-based technologies to food in an uncertain public knowledge context; however, a few key differences exist. For example, GM foods involve primarily "genetic" changes to ingredients, whereas nano-food applications usually apply "chemical" or structural changes (Kuzma and Priest 2010). GM foods are already prevalent on the market, while nano-foods are just emerging (Zhou 2013; Zhou et al. 2013). GM foods have had high profile media and policy debates (e.g., California's recent labeling proposition), whereas nano-foods have not. Given the mixture of similarities, contrasts, and differing market prevalence, we aimed to compare consumer preferences for labeling and WTB for these two technologies applied to food and explore factors influencing both. We also set out to consider factors that influence a desire for labels on GM and nano-food

products and in turn, how labeling influences WTB. Given the projected rise in the current and expected use of GM and nano-foods, it is vital to better understand the desires for labeling and the complex mixture of influential factors.

Specifically, this study employs structural equation modeling (SEM) to estimate the relationships between perceptual influences of consumers including trust in government technology management, risk and benefit attitudes, and labeling preferences on consumer's WTB GM and nano-food products. In this study, we test hypotheses formed by the literature, including the studies mentioned above, while adding the direct comparison of the two emerging technologies in order to inform future research and policy decisions.

## Theoretical framework and proposed hypothesis

SEM is a statistical technique that allows for the simultaneous estimation of a series of separate, but interdependent relationships between latent constructs (Bagozzi 1994). Latent constructs embody constructs that cannot be observed directly, and therefore, SEM can relate consumers' purchase intentions to their general attitudes and social beliefs (which are usually assumed to be measured with error) (Fishbein and Ajzen 1975; Kim 2009; Rodríguez-Entrena et al. 2013). SEM embraces both dependent and interdependent relationships, which can be considered as an extension to multiple regressions (Aaker and Bagozzi 1979; Bollen 1998). It has two major advantages in analyzing people's unobserved preferences: (1) the technique extends traditional multivariate statistical analysis (e.g., multiple regression) in that it estimates errors involved in psychometric relationships and it provides tests of goodness-of-fit for hypothesized theoretical models (Michaelidou and Hassan 2010). (2) SEM can simultaneously estimate the relationship between observed variables and unobserved latent variables, and the relationship between latent variables. The standard SEM consists of two parts, namely the measurement model (confirmatory factor analysis) specifying the relationships between the latent variables and their constituent observed variables, and the structural equation model estimating the causal relationships between the latent variables (Toma et al. 2011).

The SEM framework of consumer research has been used by researchers in various fields. Shaw and Shiu (2002) used SEM to assess the importance of ethical obligation and self-identity in ethical consumers' decision-making. Hellier et al. (2003) used SEM to incorporate customer perceptions of equity and value and customer brand preference into an integrated repurchase intention analysis. Worsley et al. (2013) applied two SEM models to estimate how food safety and health concerns influence men and women's dietary and physical activities in Australia. Within previous SEM applications, there are considerable amount of studies on public perceptions toward biotechnology across countries. Saba and Vasallo (2002) tested Italian consumer attitudes toward the use of gene technology for tomato products. Grunert et al. (2003) evaluated consumer perceptions of GM food in four Nordic countries. More recently, Martinez-Poveda et al. (2009) employed SEM to investigate the factors affecting consumer-perceived risks for GM food in Spain.

Furthermore, our framework was partially inspired by the previous research on how various latent variables affect consumer preferences and willingness to buy GM products. Bredahl (1999) found that perceived risks and benefits of genetic modification significantly impact consumer attitudes toward GM foods, which in turn affects consumer purchasing intention of GM foods. Siegrist (2000) and Verdurme and Viaene (2003b) found consumers' confidence and trust in institutions (e.g., FDA) play an important role in forming attitudes toward GM foods. Chen and Li (2007) analyzed a consumer SEM model in Taiwan, and found that trust in scientists positively affects peoples' preference for GM food, while knowledge had a negative impact. Previous research also has shown consumers' socio-economic characteristics and religious background influence their perceptions of GM foods (Ganiere et al. 2006; Hoban 1998; Rodríguez-Entrena et al. 2013).

While there are numerous SEM studies on GM food, this multivariate technique has seldom been applied to nano-food. Thus, based on the findings from previous research, we propose a SEM framework (Fig. 1) to fill this knowledge gap, and especially to compare consumer attitudes toward GM food and nano-food, as measured by risk and benefit perception and comfort with consumption, in the same experimental set-up. There are five latent variables in the

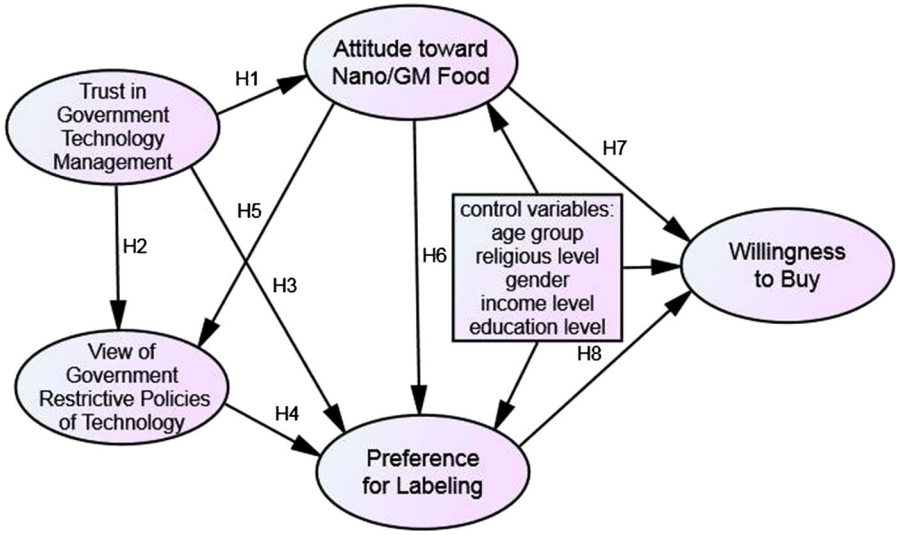


**Fig. 1** Theoretical framework

SEM framework, including consumers' trust in government's ability to manage GM technology or nanotechnology (TGM), consumers' view about governmental policies restricting the use of GM technology or nanotechnology in food products (VGP), general attitudes toward GM food (risk–benefit heuristics and comfort) or nano-food (ATF), consumer preference for labeling GM technology or nanotechnology in food products (PLB), and consumers' willingness to buy (WTB) GM food or nano-food. In addition, we also explore how consumer socio-demographic characteristics affect general attitudes toward GM food or nano-food, their preference for labeling and WTB GM food or nano-food. Below we describe each of the variables in more detail. Tables 1 and 2 show detailed information on latent variables and their associated reflective indicators, and the survey questions and order are provided in the supplementary material in Appendix A.

### Trust in government technology management (TGM)

Trust in governing agencies has been shown to be an essential factor influencing consumer attitudes and intentions. It is logical that "trust in government ability to manage a technology" would lead to more trust in safety of technology, especially if government has a protective role. It could also affect consumer intentions of purchasing food produced using the technology. This factor is thought to be especially important when consumers have little information or knowledge about a new technology such as nanotechnology (Siegrist 2000). Several studies have shown trust in governing agencies significantly affects the acceptance of GM application in food products. Verdurme and Viaene (2003a) mentioned that trust in governing agencies is a fundamental factor in consumers' perception or attitude toward GM foods, in that the long-term effect of GM foods on human health or environment remains unknown. Frewer et al. (2004) and Chen and Li (2007) stated trust in government or institution is particularly important if the public perceive they have no control over society's adoption of a new technology. Recent research by Rodríguez-Entrena et al. (2013) concluded that consumer trust in institutions is positively related to their attitude toward technology applications in food. Three hypotheses pertaining to trust in governing agencies were proposed and tested in our SEM:

**Hypothesis 1** Trust in government technology management increases the positive attitude toward GM food or nano-food (H1).

**Hypothesis 2** Trust in government technology management increases consumer support for governmental restrictive policies of using GM technology or nanotechnology in food products (H2).

**Hypothesis 3** Trust in government technology management increases consumer preference for labeling

**Table 1** Constructs and indicators for GM food

| Code | Constructs (latent variables) | Indicators (observed variables) | Scale | Average | SD | Cronbach's alpha |
|---|---|---|---|---|---|---|
| TGM | Trust in government technology management | What level of trust do you have in the FDA to effectively ensure the safety of GM ingredients? | 1 to 5<br>1 = Strongly distrust<br>5 = Strongly trust | 2.99 | 1.02 | 0.89 |
| | | If food products containing GM ingredients are labeled with an additional GM label, how much do you trust the FDA to effectively regulate and enforce the additional label? | | 2.88 | 1.04 | |
| VGP | View of government restrictive policies of GM | Governmental policies restricting the use of food products containing GM ingredients will benefit the environment | 1 to 5<br>1 = Strongly disagree<br>5 = Strongly agree | 3.14 | 0.91 | 0.72 |
| | | Governmental policies restricting the use of food products containing GM ingredients will benefit the US economy | | 3.04 | 0.83 | |
| | | Governmental policies restricting the use of food products containing GM ingredients will benefit human health | | 3.34 | 0.95 | |
| ATF | Attitude toward GM food | How comfortable are you with the idea of consuming GM food ingredients? | 1 to 5: 1 = very uncomfortable/ Risk strongly outweigh benefits | 2.73 | 1.13 | 0.86 |
| | | How do you think benefits compare to risks for GM food ingredients, in general? | | 2.91 | 1.17 | |
| PLB | Preference for labeling GM food | Food products containing GM ingredients should be labeled with an additional label identifying the presence of GM ingredients | 1 to 5<br>1 = Strongly disagree<br>5 = Strongly agree | 3.61 | 1.15 | 0.70 |
| | | Labeling food products that contain GM ingredients should be mandatory | | 4.13 | 0.84 | |
| WTB | Willingness to buy food products produced with GM ingredients | How willing would you be to buy food products containing GM ingredients… | 1 to 5<br>1 = Strongly unwilling to buy<br>5 = very willing to buy | | | |
| | | If they were sold at the same prices as foods made without GM ingredients? | | 2.83 | 1.13 | 0.97 |
| | | If they were sold by your most preferable brand and at the same prices as foods made without GM ingredients? | | 2.90 | 1.12 | |
| | | If they were sold at the same prices by your preferred brand, and were nutritionally enhanced (more nutrients, better absorption, etc.), compared to foods made without GM ingredients? | | 3.08 | 1.17 | |
| | | If they were sold at the same prices by your preferred brand and had an improved taste, compared to foods made without GM ingredients? | | 3.00 | 1.18 | |
| | | If they were sold at the same prices by your preferred brand, and caused less pollution during their production, compared to foods made without GM ingredients? | | 3.05 | 1.15 | |

**Table 2** Constructs and indicators for nano-food

| Code | Constructs (latent variables) | Indicators (observed variables) | Scale | Average | SD | Cronbach's alpha |
|---|---|---|---|---|---|---|
| TGM | Trust in government technology management | What level of trust do you have in the FDA to effectively ensure the safety of nano-ingredients? | 1 to 5<br>1 = Strongly distrust<br>5 = Strongly trust | 2.82 | 1.05 | 0.90 |
| | | If food products containing nano-ingredients are labeled with an additional nano-label, how much do you trust the FDA to effectively regulate and enforce the additional label? | | 2.96 | 1.04 | |
| VGP | View of government restrictive policies of ENM | Governmental policies restricting the use of food products containing nano-ingredients will benefit the environment | 1 to 5<br>1 = Strongly disagree<br>5 = Strongly agree | 3.06 | 0.84 | 0.73 |
| | | Governmental policies restricting the use of food products containing nano-ingredients will benefit the US economy | | 3.07 | 0.84 | |
| | | Governmental policies restricting the use of food products containing nano-ingredients will benefit human health | | 3.23 | 0.92 | |
| ATF | Attitude toward nano-food | How comfortable are you with the idea of consuming nano-food ingredients? | 1 to 5: 1 = very uncomfortable/ Risk strongly outweigh benefits | 2.84 | 1.10 | 0.86 |
| | | How do you think benefits compare to risks for nano-food ingredients, in general? | | 2.67 | 1.10 | |
| PLB | Preference for labeling nano-food | Food products containing nano-ingredients should be labeled with an additional label identifying the presence of nano-ingredients | 1 to 5<br>1 = Strongly disagree<br>5 = Strongly agree | 4.16 | 0.84 | 0.66 |
| | | Labeling food products that contain nano-ingredients should be mandatory | | 3.64 | 1.16 | |
| WTB | Willingness to buy food products produced with nano-ngredients | How willing would you be to buy food products containing nano-ingredients… | 1 to 5<br>1 = Strongly unwilling to buy<br>5 = very willing to buy | | | 0.97 |
| | | If they were sold at the same prices as foods made without nano-ingredients? | | 2.81 | 1.0.8 | |
| | | If they were sold by your most preferable brand and at the same prices as foods made without nano-ingredients? | | 2.86 | 1.09 | |
| | | If they were sold at the same prices by your preferred brand, and were nutritionally enhanced (more nutrients, better absorption, etc.), compared to foods made without nano-ingredients? | | 3.02 | 1.13 | |
| | | If they were sold at the same prices by your preferred brand and had an improved taste, compared to foods made without nano-ingredients? | | 2.96 | 1.13 | |
| | | If they were sold at the same prices by your preferred brand, and caused less pollution during their production, compared to foods made without nano-ingredients? | | 2.99 | 1.12 | |

GM ingredients or nano-ingredients in food products. (H3).

### View of government restrictive policies of technology (VGP)

Consumer views of government restrictive policies for a technology reflect their concern and precaution about the use of the technology. On one hand, VGP partially reflects that consumers with more concerns about a new technology would be more supportive of the policies restricting the use of the technology. On the other hand, cautious people would relate food technology with potential negative outcomes regardless of their knowledge about the technology. Michaelidou and Hassan (2010) stated that cautious and responsible consumers are aware of and concerned about their well-being by engaging in behaviors that maintain a good state of environment and health. Hence, three Likert questions were designed to obtain consumers' degree of agreement with the statements that governmental policies restricting the use of food products containing nano-material/GM ingredients will benefit the environment, US economy, or human health. Specifically, we test the following hypothesis:

**Hypothesis 4** Positive view of government restrictive policies of technology leads to stronger preference for labeling GM ingredients/nano-ingredients in food products (H4).

### Attitude toward nano-food and GM food (ATF)

Previous research indicates that consumer's attitude is measured as the degree of favor or disfavor of an object (Eagly and Chaiken 1993). Verdurme and Viaene (2003a) concluded that consumers' purchase intentions are influenced by their attitude toward the product. Rodríguez-Entrena et al. (2013) found a significant positive relationship between consumer attitudes toward GM food and their purchase intention. Nano-food is relatively new compared with GM food and understanding consumers' attitude of nano-food could provide better prediction of consumer acceptance of nano-food in the near future. To assess consumers attitude toward GM food and nano-food, we asked consumers questions including: how comfortable are they with the idea of consuming GM food or nano-food; and how do they think the benefits compare to risks for GM food or nano-food. This combination of questions about risk, benefit, and comfort relate to key attitudinal factors previously identified in the literature for nano-foods from a survey with a convenience sample in Switzerland (Siegrist et al. 2007). We wanted to test whether these attitudinal factors relate to view of government policies (VGP) and preferences for labeling (PFB), which were not included in the Swiss study. We also wanted to see if they associated with WTB in our nationally representative, US sample, and whether there were any differences between GM and nano-foods.

Thus, our model tests three hypotheses related to acceptance and risk and benefit attitudes toward GM and nano-foods:

**Hypothesis 5** Consumers with positive attitude toward nano-food or GM food would reduce their degree of support for government restrictive policies of nanotechnology or GM technology (H5).

**Hypothesis 6** Consumers with positive attitude toward nano-food or GM food decrease consumer preference for labeling nanotechnology or GM technology on food products (H6).

**Hypothesis 7** Consumers with positive attitudes toward nano-food or GM food tend to have increased purchasing intention of nano-food or GM food (H7).

### Preference for labeling (PLB)

Labels are a direct communication element designed to assist consumers in making informed purchasing decisions. To our knowledge, no SEM studies have focused on the influences of consumer labeling preference on GM or nano-foods. Previous research has conflicting findings on consumer preferences for labeling GM products. Using experimental methods, Noussair et al. (2002) found consumers do not notice GM labeling so that their demand for GM products is not affected by GM labels, which is not supportive for the existence of endogenous relationship between GM labeling and purchase intention of GM food. Rousu et al. (2005) conducted non-hypothetical field experiment and found that consumers do not always correctly interpret the meaning of scientific information on labels and are sometimes misinformed by GM labeling, which suggests that there is no direct

relationship between GM labeling and consumer willingness to buy GM food. Furthermore, Loureiro and Hine (2004) found that the premium associated with mandatory labeling for GM is lower than the corresponding costs. However, another body of the literature found GM labeling significantly affects consumers' willingness to buy GM food product (Huffman 2003; Roe and Teisl 2007), and that the framing of the label as benefit gained or risk avoided matters (Phillips and Hallman 2013). For nano-food, recent research in Europe found consumer attitudes toward risks and benefits of sunscreens (Siegrist and Keller 2011) and willingness to buy nano-food is negatively affected by labeling nano-ingredients (Bieberstein et al. 2013; Katare et al. 2013). Thus, we aim to explore the relationship between consumer preference for labeling of GM food or nano-food and willingness to buy GM food or nano-food. Specifically, we test the following hypothesis:

**Hypothesis 8** The more consumers prefer to label the nanotechnology or GM technology on food products, the less they are willing to buy nano-food or GM food (H8).

### Controlled demographics

We are also interested in understanding how consumer socio-demographics affect their attitude toward, labeling preference for, and WTB nano-food or GM food. Hossain et al. (2004) conducted a national survey to measure consumers' WTB for GM food, and their results suggested that younger, white, male, and college educated individuals are more likely to accept the use of biotechnology in food products. Gender and race have been found to influence risk perception for health and technology risk, called a "white male" effect as this group rates risks lower than females or underrepresented minorities (e.g., Finucane et al. 2000; Palmer 2003). Previous research has also indicated that age tends to be a major factor influencing food consumption (Dean et al. 2009). Women usually consider more of technological and nutritional aspects of food products compared to men and they are more concerned about safety and health issues (Worsley et al. 2013). Consumers with higher income tend to have a less negative attitude toward GM food and in turn have an increased purchase intention (Michaelidou and Hassan 2010). Meanwhile, religious level also plays an important role that negatively influences the acceptance of technology use in food products (Chern et al. 2002) and it has also been correlated with consumer attitudes toward nanotechnology in the US and EU (Scheufele et al. 2008). Following such previous findings, our study assesses how consumer socio-demographics such as age, religious level, gender, income level, and education level affect their attitude toward GM food or nano-food, their preference for labeling GM ingredients or nano-ingredients, and their WTB GM food or nano-food. Age, gender, income level, and education level are single indicator latent variables.

### Willingness to buy food products produced with technology (WTB)

This study examines a variety of influences on consumer's willingness to buy for GM and nano-food products. Specifically, we test (1) how consumer attitude toward GM food or nano-food affects their WTB GM food or nano-food (H7), (2) how consumer preference for labeling the GM ingredients or nano-ingredients affect their WTB (H8), and (3) how consumers' socio-demographic backgrounds affect their WTB for GM food or nano-food. Previous studies have been done to address above relationships (Siegrist et al. 2007). Using SEM analysis, Chen (2008) found that people in Taiwan are willing to buy GM food, because they perceive more benefits than risks from biotechnology and form a positive attitude toward GM food. Cook and Fairweather (2007) provided an early assessment of key influences on consumer intentions to purchase lamb or beef using nanotechnology and their results indicated that the nano-food is more acceptable than GM food, and consumer attitude, subjective norm, perceived behavioral control, and self-identity are the major factors influencing consumer purchase intention of nano-food. Siegrist et al. (2009) examined consumers' WTB nano-food and suggested that consumers form a negative utility from consuming nano-food regardless of nano-products' clear benefits.

## Research methodology

### Sampling method

Our data were collected online through the professional survey company Qualtrics. Qualtrics has been

recognized by its high-quality service to provide extensive and representative consumer samples, and the service has become increasingly popular for data collection among academic researchers from different fields around the world. Saunders et al. (2013) gathered a sample of 2067 respondents through Qualtrics panel, and analyzed consumers' willingness to pay for food quality attributes across China, India, and United Kingdom. Huang et al. (2013) used Qualtrics to get a representative sample of US population and estimated consumer preferences for the predictive genetic test for Alzheimer disease. The survey was administered to 1,145 people from all geographic regions of the US over the Internet. Sampling was facilitated by Qualtrics to reflect a representative sample of US participants given the socio-demographic and socio-economic variables used in our analysis including age, gender, education level, household income, race/ethnicity, religiosity, and political ideology.

### Analytical procedure

Before the estimation of SEM, we first employed confirmation factor analysis to (1) approximate unobserved latent variables using observed variables, and to (2) assess the reliability and validity of our theoretical framework. Confirmatory factor analysis (CFA) tests the invariance for all latent variables simultaneously when observed variables are constrained for identification (Millsap and Kwok, 2004). We also calculated Cronbach's alpha values for each latent variable. When the Cronbach's alpha value is higher than the minimum threshold of 0.70 the latent variable is considered as reliable (Nunnally and Bernstein 1978).

SEM was then applied to analyze our proposed theoretical framework. SPSS 21.00 (2013) software was used to clean and analyze our dataset. Specifically, the AMOS 21.00 (2013) program was adopted for CFA and SEM model construction and estimation. We conducted several statistical tests for the goodness-of-fit of the CFA and SEM models. The tests include Chi square fit test (CMIN/DF), standardized root mean square residual (SRMR), root mean square errors of approximation (RMSEA), Tucker-Lewis index (TLI), goodness-of-fit index (GFI), and comparative fit index (CFI). We have a relatively large sample size, which might produce a problematic Chi square index, and CMIN/DF is able to adjust Chi square statistics for the degree of freedom. According to Arbuckle (2005), the goodness-of-fit is acceptable when CMIN/DF is less than 5 and the more conservative acceptable thresholds are between 2 and 3. The RMSEA incorporates a discrepancy function criterion (comparing observed and predicted covariance matrices) and a parsimony criterion. CFI and GFI are derived from a comparison of the hypothesized model and the independent model. A SEM model is considered to have good goodness-of-fit if the model meets the following criteria: Chi square probability $p < 0.05$, CMIN $< 5$, SRMR $< 0.05$, RMSEA $< 0.05$ (Hu and Bentler 1999), TLI $> 0.95$, and CFI $> 0.95$ (Bentler 1990).

## Results and discussion

### Data description

Table 3 summarizes the socio-demographic information of the 990 participants. A total of 1,145 completed surveys were received, and 155 surveys were discarded due to incomplete information. The average age of the sample is approximately 48. The average education level is some college degree (associate degree included) and the average household income is about $50,000. Forty-nine percent of participants were male. In addition to the basic demographics, our study also collected information on participants' religious background. According to five religion-related questions, the average religious image for a sampled participant is someone who attends religious service less than once a month, considers themselves as a moderate person between liberal and conservative and somewhat religious, makes daily life decisions guided by religion to a little extent, and views science and technology without too much influence by religiosity. The last column of Table 3 shows the mean of age, income, gender, education, and race of the US population based on US census data. Our sample is consistent with the US census data (DeNavas-Walt et al. 2010) in terms of age (age group 15–83), gender, and education. However, our household income level of the sampled participants is slightly lower than the mean income reported by the US census.

**Table 3** Explanation and Statistics of Demographics

| Demographic characteristic | Explanation | Mean (SD) | US census |
|---|---|---|---|
| Age | Age of respondents | 47.58 (15.59) | 45.16 |
| Education | Highest educational level completed:<br>1 = Less than high school<br>2 = Some high school<br>3 = High school(includes GED)<br>4 = Some college (includes associate degree)<br>5 = College graduate (BS, BA, etc.)<br>6 = Some graduate education<br>7 = Graduate degree (MA, MS, PhD, JD, MD, etc.) | 4.35 (1.27) | 4.39 |
| Income | Total family income in 2012, before taxes and other deductions:<br>1 = Less than $25,000<br>2 = $25,000–$50.000<br>3 = $50,000–$75,000<br>4 = $75,000–$100,000<br>5 = $100,000–$150,000<br>6 = More than $150,000 | 2.83 (1.36) | 3.05 |
| Gender | 0 = Female; 1 = Male | 0.49 (0.50) | 0.49 |
| Religious service | How often have you attended religious services in the past year:<br>1 = More than once a week<br>2 = About once a week<br>3 = 2–3 times a month<br>4 = About once a month<br>5 = Less than once a month<br>6 = Only on special holy days<br>7 = About once a year<br>8 = Have not attended | 5.20 (2.55) | – |
| Religious level | How religious would you say you are:<br>1 = Very religious<br>2 = Somewhat religious<br>3 = Not too religious<br>4 = Not religious at all | 2.36 (0.97) | – |
| Religious decision | How much does religion guide the decisions you make on a daily basis:<br>1 = Not at all; 2 = Not too much; 3 = A little;<br>4 = Some; 5 = Mostly; 6 = A great deal; 7 = Completely | 3.62 (1.94) | – |
| Religiosity view | How much does religiosity affect you view issues relating to science and technology:<br>1 = Not at all; 2 = Not too much; 3 = A little;<br>4 = Some; 5 = Mostly; 6 = A great deal; 7 = Completely | 2.63 (1.74) | – |
| Ideology | How would you scale your level from “liberal” to “conservative”:<br>1 = Very liberal; 2 = Somewhat liberal; 3 = Moderate;<br>4 = Somewhat conservative; 5 = Very conservative | 3.05 (1.11) | |

Reliability and validity

In order to assess the reliability and validity of the two models for nano-food and GM food, our initial measurement models were evaluated via CFA. The goodness-of-fit indices in Table 4 showed that our proposed constructs are valid and reliable. The CMIN/DF value is below 3 which is good according to Carmines and McIver (1981). AGFI, CFI, NFI, and TLI are all greater than the suggested criteria of 0.9 for the measurement model, and RMSEA is also more than acceptable compared with a recommended minimum of 0.05 (Hu and Bentler 1999). As for the estimation of Cronbach's Alpha value of each construct (TGM, VGP, ATF, PLB, and WTB), according to Tables 1 and 2, the values for GM food and nano-food are 0.89/0.90, 0.72/0.73, 0.86/0.86, 0.70/0.66, and 0.97/0.97, respectively. The goodness-of-fit indices indicate the constructs of latent variables are reliable and valid to be used in the SEM models.

Estimation results for structural equation modeling

According to Table 4, the goodness-of-fit results for the SEM models are acceptable for both nano-food and GM food. Therefore, Table 5 provides valid and reliable results for the structural equation modeling estimates. The SEM estimation results show the estimated coefficients have clear similarities and differences between the nano-food model and the GM model. Figures 2 and 3 further provide visualized comparison between the estimation results of two models.

The SEM results show three significant and positive causal relationships between latent variables. Consumer trust in government technology management positively impacts consumer attitudes toward the GM food or nano-food (H1), and consumer attitudes toward GM or nano-food, as measured by risk–benefit comparisons and comfort with consumption, significantly affect their WTB GM or nano-food (H7), so consumer attitude serves well as a mediator between consumer trust in government technology management and consumer WTB. The support of hypothesis H7 provides justification that consumer purchase intention of GM food or nano-food is significantly dependent on their attitudes toward the two types of foods. The results also show an indirect positive causal relationship between trust in government and WTB. In addition, consumer willingness to label GM technology or nanotechnology on food products is positively and significantly impacted by their positive view of government restriction policies for nano-food or GM food (H4).

The estimation results show two significant and negative causal relationships between the latent variables. Consumer attitudes toward GM food or nano-food, measured by risk and benefit comparisons and comfort with consumption, significantly impact their view of government restrictive policies on the two types of foods, which means consumer negative attitude toward GM food or nano-food increases consumer's positive view or support of government restrictive policies of GM technology or nanotechnology (H5). However, the negative impact is significantly larger for GM food than nano-food. Additionally, consumer positive attitude toward GM food or nano-food also significantly decreases consumer preference for labeling of the two technologies on food products (H6), and this indicates that the more positive attitude consumers have toward GM food or nano-food, the less they prefer to label the technology information on food products.

Several of the hypotheses are not supported. For example, H3 is not supported for both GM food and nano-food models as no direct relationship is observed between consumer trust in government technology management and consumer preference for labeling the technologies. Furthermore, H2 is not supported for the

**Table 4** Goodness-of-Fit Indices for CFA and SEM models

| Fit | $\chi^2$ | CMIN/DF | CFI | GFI | NFI | TLI | RMSEA | AGFI | AIC |
|---|---|---|---|---|---|---|---|---|---|
| Measurement of model invariance (CFA) | | | | | | | | | |
| Nano-food | 170.35 | 2.18 | 0.95 | 0.96 | 0.91 | 0.93 | 0.04 | 0.93 | 254.35 |
| GM food | 121.45 | 1.58 | 0.97 | 0.97 | 0.93 | 0.96 | 0.02 | 0.95 | 207.45 |
| Structure model invariance (SEM) | | | | | | | | | |
| Nano-food | 360.38 | 2.47 | 0.90 | 0.99 | 0.85 | 0.98 | 0.04 | 0.99 | 488.38 |
| GM food | 276.73 | 1.94 | 0.94 | 0.99 | 0.88 | 0.92 | 0.03 | 0.99 | 410.73 |

**Table 5** SEM estimation results

| | Coefficient (S.E.) | | Standardized coef. | | Test results for hypotheses | |
|---|---|---|---|---|---|---|
| | Nano-food | GM food | Nano-food | GM food | Nano-food | GM food |
| H1: TGM → ATF | 0.517***[a] (0.031) | 0.547*** (0.035) | 0.529 | 0.546 | Supported | Supported |
| H2: TGM → VGP | 0.038 (0.021) | 0.091*** (0.026) | 0.089 | 0.162 | Not supported | Supported |
| H3: TGM → PLB | −0.005 (0.024) | 0.028 (0.023) | −0.007 | 0.047 | Not supported | Not supported |
| H4: VGP → PLB | 0.241*** (0.060) | 0.235*** (0.043) | 0.154 | 0.222 | Supported | Supported |
| H5: ATF → VGP | −0.124*** (0.025) | −0.270*** (0.030) | −0.282 | −0.480 | Supported | Supported |
| H6: ATF → PLB | −0.366*** (0.031) | −0.320*** (0.032) | −0.536 | −0.538 | Supported | Supported |
| H7: ATF → WTB | 0.835*** (0.037) | 0.935*** (0.042) | 0.787 | 0.886 | Supported | Supported |
| H8: PLB → WTB | −0.134** (0.053) | 0.060 (0.068) | −0.086 | 0.034 | Supported | Not supported |
| Age → ATF | −0.017 (0.017) | 0.004 (0.017) | −0.027 | 0.006 | Not supported | Not supported |
| Age → PLB | 0.091*** (0.13) | 0.073*** (0.011) | 0.209 | 0.193 | Supported | Supported |
| Age → WTB | −0.002 (0.015) | −0.001 (0.015) | −0.002 | −0.002 | Not supported | Not supported |
| Gender → ATF | −0.348*** (0.051) | −0.352*** (0.054) | −0.182 | −0.181 | Supported | Supported |
| Gender → PLB | 0.017 (0.038) | 0.087* (0.036) | −0.013 | 0.075 | Not supported | Supported |
| Gender → WTB | 0.041 (0.041) | 0.031 (0.0423) | 0.020 | 0.015 | Not supported | Not supported |
| Income → ATF | 0.070*** (0.22) | 0.053* (0.023) | 0.097 | 0.072 | Supported | Supported |
| Income → PLB | 0.011 (0.015) | 0.024 (0.014) | 0.023 | 0.055 | Not supported | Not supported |
| Income → WTB | −0.008 (0.016) | −0.027 (0.017) | −0.010 | −0.035 | Not supported | Not supported |
| Education → ATF | 0.048 (0.025) | −0.001 (0.025) | 0.060 | −0.001 | Not supported | Not supported |
| Education → PLB | 0.022 (0.016) | 0.007 (0.015) | 0.040 | 0.015 | Not supported | Not supported |
| Education → WTB | −0.032 (0.018) | −0.026 (0.018) | −0.038 | −0.026 | Not supported | Not supported |
| Religion → ATF | 0.007 (0.019) | −0.026 (0.020) | 0.012 | −0.040 | Not supported | Not supported |
| Religion → PLB | 0.018 (0.013) | 0.020 (0.012) | 0.040 | 0.051 | Not supported | Not supported |
| Religion → WTB | 0.005 (0.014) | 0.042** (0.014) | 0.008 | 0.061 | Not supported | Supported |

[a] A single asterisk (*), double asterisks (**), and triple asterisks (***) denote significance at 5, 1, and 0.1 % levels, respectively

nano-food model but H2 is supported for the GM food model, which means consumer trust in government technology management does not significantly impact consumer support of governmental restrictive policies for nano-food, but it does significantly impact consumer support of governmental restrictive policies on GM food. Lastly, for nano-food, the more consumers want nano-ingredients labeled, the less they are willing to buy nano-food. While for GM food, consumer preference for labeling GM does not significantly affect their WTB GM food.

Our results show that some socio-demographic variables also have significant impacts on the latent variables for both GM food model and nano-food model. We found the following positive relationships: the older the consumers, the more they would prefer to have the technologies labeled on food products; the higher the income level, the more the consumers would have positive attitude toward nano-food or GM food; the more religious the consumers, the more they would prefer to label the technologies; and male consumers tend to have positive attitudes toward the technologies more than female consumers (indicating higher benefit to risk weighting and comfort among males). Level of educational attainment did not impact the latent variables for either model.

We also found some differences between the impacts of socio-demographic variables on some of the latent variables for GM food and nano-food. For instance, while consumers' religious levels do not significantly affect their WTB nano-food but they do significantly and positively affect consumers' WTB GM food. Additionally, female consumers tend to prefer labeling of GM food more than male

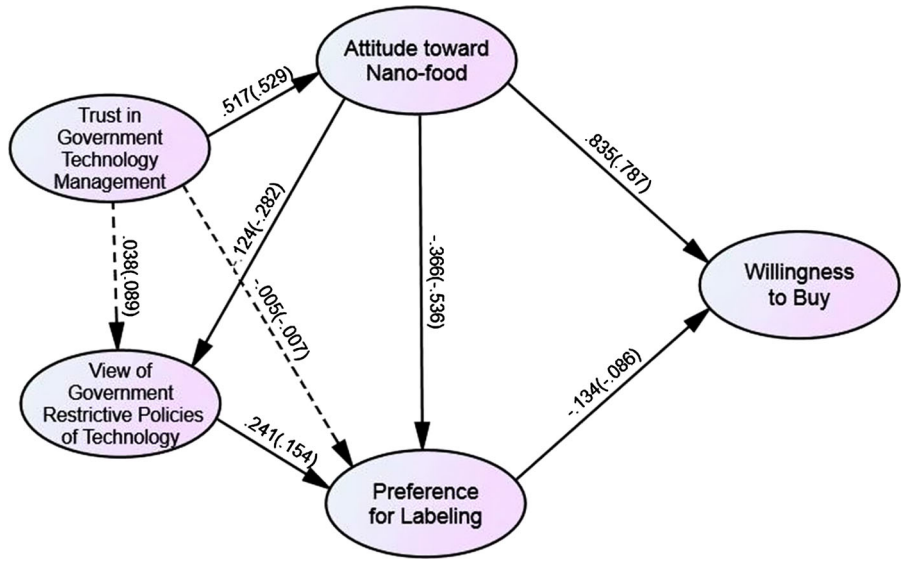


**Fig. 2** Unstandardized (standardized) path estimates for nano-food model

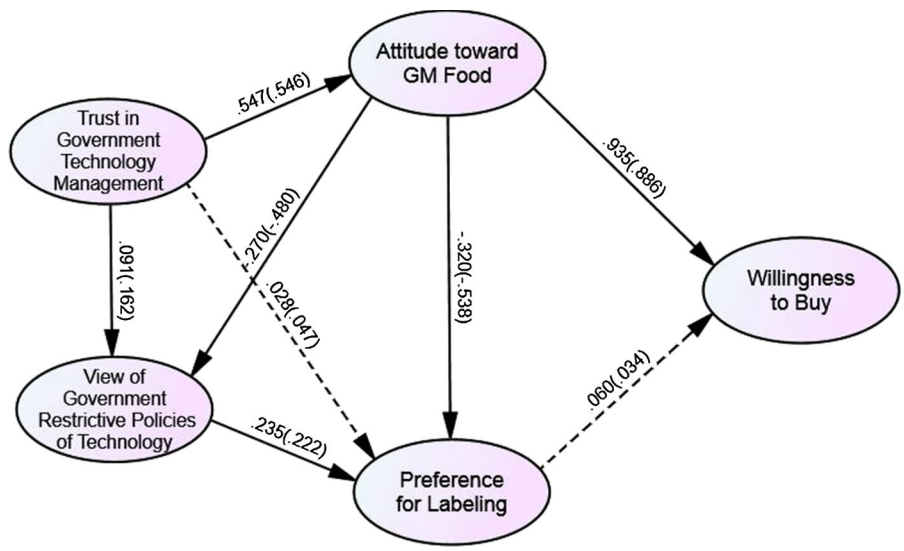


**Fig. 3** Unstandardized (standardized) path estimates for GM food model

consumers, but female consumers do not have a stronger purchase intention than male consumers.

Based on the estimated results, we can draw several conclusions: older consumers tend to prefer to label GM technology or nanotechnology on food products than younger consumers but age does not significantly affect consumer attitudes toward and purchase intention of GM food or nano-food; female consumers are more perceptive of the negative aspects of GM technology or nanotechnology, but this heightened perception does not necessarily lead to decreased WTB GM food or nano-food; consumers with higher income tend to have more positive attitudes toward nano-food and GM food; consumers' education level does not have significant impacts on consumer attitude toward WTB and preference for labeling GM food or nano-food; and more religious consumers do not have stronger preferences for labeling the two types of technologies on food products.

## Discussion

Consumer perceptions and attitudes toward nano-food and GM food, as well as the factors that do or do not

influence them share considerable similarities but also exhibit some interesting differences. Here we discuss our study findings about the influencing factors on consumer WTB GM and nano-food products and their desires for labeling.

First, consumers' attitudes toward nano-food or GM food are positively correlated to their trust in government technology management, which means consumers who have more trust in government technology management tend to possess more positive attitudes toward nano-food or GM food as measured by their risk–benefit perceptions and comfort with consumption. This is consistent with previous studies that demonstrated the causal and positive relationships between consumers' trust in government and attitude toward GM food (Moon and Balasubramanian 2001), as well the claim that trust in government can be an indicator of the acceptability of GM food (Poortinga and Pidgeon 2005).

Second, consumers' view of governmental restrictive policies of nanotechnology and GM technology positively affect their preference for labeling the technologies on food products. The more that consumer's support restricting the applications of the technologies in food products, the more they want technology information to be labeled. This relationship was also similar for consumers' attitudes about GM and nano-foods—more negative attitudes about GM and nano-food correlate to an increased desire for labeling. This is further supported by previous values-based findings that a majority of consumers support labeling of GM and nano-food technologies while maintaining a reluctance to consume GM foods (Brown and Kuzma 2013; Frewer et al. 2013). In this sense, it is important to note that for some consumers, labels of this type likely represent a heuristic warning cue about the product rather than serve as a locus for information conveyance about the product. What may be occurring is a desire for labels to serve as technology declarations that would serve as "do not buy" warnings among reluctant consumers.

Third, many previous studies have demonstrated a strong relationship between attitudes toward the products and purchase intentions (Chen and Li 2007; Rodríguez-Entrena et al. 2013), and this study supports that having a positive attitude toward nano-food/GM food is a crucial element for increasing consumers' purchase intention. In particular, views of risks and benefits have been found to influence WTB or acceptance in numerous other studies (see "Introduction" section) and we also found that here in our study.

Last, for nano-food and GM food, there is no significant relationship between consumer trust in government and their preference for labeling the technologies on food products. In other words, higher trust in government does not mean higher desires for labeling, nor does lower trust mean lower desires for labeling. Higher trust does not mean lower desires for labeling and lower trust does not mean higher desires either. This is an interesting finding and perhaps suggests that labeling is mediated by other factors like rights to know and choose, rather than trust to ensure safety. The role of labeling may not be seen as a government restrictive policy to ensure safety, but rather could be performed to provide a choice.

Besides the similarities between the estimation results for nano-food and GM food, differences between consumers' perceptions for nano-food and GM food also exist and provide important insights. For the relationship between consumers' trust in government and their view of technology restriction, our results show that consumers' trust in government does not affect their view of the policies of restricting nano-food, but it does positively affect their view of the policies restricting GM food. In other words, for GM food, higher trust in government relates to higher desires for restrictive government policies and lower trust in government relates to lower desires for restrictive policies. While for nano-food, trust does not matter for restrictive policies. This difference could be affected by the history of consumer awareness of the risks associated with GM food as it has had higher media profile media debates in the past decades, whereas nano-food is relatively new and does not have as much media exposure. The relationships between consumer attitude toward the technologies and their view of the restrictive policies are positive for both nano-food and GM food, but the standardized coefficient for the GM model is significantly larger than that of the nano-food model. Therefore, because of the high exposure of GM food in the media, consumers are more eager for policies restricting GM food if they trust the governing bodies than they are for restricting nano-food. Thus, there could still be ambivalence toward nano-foods and government regulatory policy.

Lastly, another interesting difference is that consumers' preference for labeling nano-food correlates

to a negative WTB nano-food, whereas their preference for labeling GM food does not correlate either positively or negatively with WTB GM food. There could be a tighter coupling of WTB and desires for a label with nano-foods because of the unfamiliarity. In other words, labeling for nano-foods could be desired as a heuristic to decide based on information and possibly safety, whereas with GM foods it could involve a desire for a right to choose. In previous work of ours with focus groups, we found that people were generally not familiar with nano-foods, that they desired labels, and viewed nano-food labeling as effective only if it comes with education and information (Brown and Kuzma 2013). Regardless, there are other plausible explanations for the difference between GM and nano-foods with respect to the correlation between WTB and labeling, including a lack of utility of GM food labeling for consumers (Loureiro and Hine 2004; Rousu et al. 2005) or that desires for GM labeling are based on other heuristics such as value-based concerns about "modifying life." More research will be needed to probe the difference.

## Conclusions and implications

The use of SEM to assess this complex system of influential factors has provided a valuable tool for comparing many previous assumptions regarding attitudes, trust, and labeling preferences on consumer WTB GM and nano-food products and desires for labels. The results suggest that trust in governing agencies to manage GM and nano-foods does not influence labeling preference but that trust does influence attitudes about the food technologies themselves. Furthermore, attitudes toward the technologies (measured by risk–benefit comparisons and comfort with consumption) greatly influence views of government restrictive policies, labeling preferences, and WTB food products that employ GM or nano-food technologies. Also, labeling preferences influenced WTB nano-foods but not GM foods. GM foods maintain a high level of desire for technology labeling, and there may be a general disposition among consumers to avoid GM foods regardless of the label. This may not be the case with the newer, and more versatile applied use of nanotechnology in food production and food packaging. Further inquiry into the motivations for consumer labeling desires in relation to purchasing intention of GM and nano-food products should be examined.

Considering socio-demographic influences, gender and household income appear to influence both attitudes for both GM and nano-food technologies, while gender and religiosity influence labeling preferences and willingness to by GM foods but not nano-foods. Again, a lack of experience with nano-foods could be a factor in this difference.

The policy importance of the GM labeling is increasing with several state bills proposed and growing national attention. Consumers desire it, but government regulations that base labeling solely on safety may not allow for it. Nano-food labeling is poised to present similar, but perhaps not identical, policy challenges. Understanding the origins of the desires for labeling and the effects of labeling, including effects on consumer purchasing decisions, could help formulate policies that strike a balance between respecting consumer desires and avoiding undue burdens on government and food industries. This study is a step in that direction.

This study also shows that not all emerging technologies are viewed the same by US consumers and that different attitudinal factors may come into play in purchasing decisions and labeling desires. Previous studies have shown that consumers are able to discern different applications of a category of emerging technologies (namely various products of nanotechnology) and have different attitudes about risks, benefits, and labeling for those applications (e.g., Brown and Kuzma 2013; Siegrist et al. 2007). This study suggests differences for categories of technologies (nanotechnology versus GM). A one-size-fits-all communication, education, engagement, or policy approach for all food technology products does not seem warranted. Better attempts to meet consumers' information, trust, and safety desires on a technology by technology basis seem possible with increasing information about attitudinal factors affecting desires for labeling and product acceptance.

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