How Information Affects Consumer Acceptance of Nano-packaged Food Products

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Abstract

Many food companies are developing nanotechnology modified food packages and it is critical to understand the informational and attitudinal factors that influence public acceptance of nano-packaging. This study uses experimental auction with real nano-packaged products to test and compare consumer acceptance for nano-packaged food products with information from various sources. The results indicate when provided with information from different sources, consumer acceptance for and attitude toward nano-packaged food products are changing: for plain-labeled food products, reliance on government regulation was the only determinant influencing participants' willingness to pay; after general information about nanotechnology was given, participants were willing to pay more for nano-packaged products, which was affected by their general attitude towards new food technology and concerns about environment/health; when detailed information were provided, concern about the environment/health became the only factor that significantly influenced participant willingness to pay for nano-packaged food products.

Keywords: Nano-package, Nanotechnology, Experimental Auction, Structural Equation Model, Information Effect, Willingness-to-Pay

1. Introduction

Nanotechnologies are frequently described as the next scientific breakthrough that will revolutionize society (Balbus, Karen, Richard, & Scott, 2006). It involves the characterization, fabrication and/or manipulation of structures, devices or materials that have at least one dimension (or contain components with at least one dimension) that is approximately 1–100 nm in length (Dowling et al., 2004). After nanotechnology was first introduced by Rochard Feynman in 1959 at a meeting of the American Physical Society (Khademhosseini & Langer, 2006), it has developed into a multidisciplinary field. In 2008, nanotechnology demanded over $15 billion in worldwide research and development money (public and private) and employed over 400,000 researchers across the globe. Its future potential is projected to impact at least $3 trillion across the global economy by 2020, and nanotechnology industries worldwide may employ at least 6 million workers by the end of the decade (Roco, Mirkin, & Hersam, 2011).

Despite the increasing opportunities surrounding nanotechnology applications, one industry which has been relatively cautious in adopting nanotechnology is the food industry. Even nanotechnology is expected to impact virtually every aspect of the food sector, nano-food and nano-packaged food products are still not commercially and widely available (Frewer et al., 2011). A major barrier for nanotechnology to be used in food industry is that some nanomaterials may have unintended effects on human health (Oberdörster, Oberdörster, & Oberdörster, 2005) and environment (Frewer et al., 2011). For example, a growing concern is that using nanomaterials in food could result in particulate nanomaterials gaining access to tissues in the human body, which could lead to possible accumulation of toxic contaminants and therefore adversely affecting human health (Cushen, Kerry, Morris, Cruz-Romero, & Cummins, 2012). Despite these concerns, nanotechnology has become increasingly popular in the food sector

(Kuzma & VerHage, 2006; Yue, Zhao, & Kuzma, 2015), and applications are already being developed in many areas of food industry, especially food packaging.

The incorporation of nanomaterials in food packaging is expected to improve the barrier properties of packaging materials (Sozer & Kokini, 2009) and should thereby help reduce the use of raw materials and prolong the shelf-life of packaged food products. In November 2008, the European Food Safety Authority (EFSA) Scientific Panel declared that nano-packages are toxicologically risk-free for food (National Nanotechnology Initiative, 2009), which was a major breakthrough for the applications of nano-packages to food products. Since then, the total nano-packaged food and beverage market has grown from $4.13 billion in 2008 to $6.5 billion in 2013, and are still estimated to grow at a compound annual growth rate of 12.7% to reach around $15.0 billion in 2020 (Bumbudsanpharoke & Ko, 2015; Consumer News and Business Channel, 2014).

The development and success of food technologies are shown to be contingent upon societal responses to their applications (Fischer, van Dijk, de Jonge, Rowe, & Frewer, 2012). However, in the case of nano-package and nano-food, the public awareness and knowledge is limited, and individuals do not have extensive experience with nanotechnology (Lee, Scheufele, & Lewenstein, 2005; Siegrist, Stampfli, Kastenholz, & Keller, 2008; Fischer, van Dijk, de Jonge, Rowe, & Frewer, 2012). As a consequence, lack of clear information decreases consumer confidence, and compromises the acceptance of new nano-products despite their social benefits (Roosen, Bieberstein, Marette, Blanchemanche, & Vandermoere, 2011). Under such situation, it is important to explore consumers' attitude towards the information on nano-packaging used for food products; and how information from difference sources may influence public opinion towards and acceptance of nanotechnology, especially nano-packaged food products.

There exist studies that focus on consumer attitudes toward nanotechnology. Cobb and Macoubrie (2004) carried out phone surveys with a sample of 1536 Americans to elicit their perceptions about nanotechnology, and found that the initial reaction was generally positive, and the perceived benefits were more prevalent than perceived risks. Gaskell, Ten Eyck, Jackson and Veltri (2005) compared preferences between the U.S. and European consumers, and concluded that the European consumers seemed to be less optimistic about nanotechnology. Furthermore, Siegrist, Stampfli, Kastenholz and Keller (2008) examined how consumers perceive nano-food and nano-packaging, and showed that even though consumers were hesitant to buy either of them, nano-package was perceived as being more beneficial than nano-food. Most recently, Yue, Zhao and Kuzma (2015) conducted choice experiments with 1117 U.S. consumers, and their results showed that compared to genetically-modified (GM) food, nano-food evoked less negative reaction. In addition to general attitude, studies have also shown that the initial attitude towards nano-packaged food products may change considerably as more detailed information becomes available. Fischer, van Dijk, de Jonge, Rowe, and Frewer (2012) conducted an experiment to investigate consumer reactions when different risk-benefit information about nanotechnology's application in food were provided, and concluded that consumer perceptions changed significantly after the provision of the information. Roosen, Bieberstein, Marette, Blanchemanche and Vandermoere (2011) evaluated the effect of information on consumers' willingness to pay (WTP) for nano-foods, and concluded that different information had significant influence on consumer WTP. Specifically, health information significantly decreased WTP, while societal and environmental information was not as important.

However, those prior studies investigating public attitudes and information effects on nanotechnology were using hypothetical instead of actual nano-products (Cobb & Macoubrie, 2004; Siegrist, Cousin, Kastenholz, & Wiek, 2007), and the estimated WTP values were hypothetical and might be biased (Bieberstein, Roosen, Marette, Blanchemanche, & Vandermoere, 2013). Our study employs experimental auctions to investigate consumers' WTP for actual nano-packaged food products. Furthermore, Structural Equation Model (SEM) is used to capture the complex relationship between attitudinal factors and consumer WTP, and how these relationships are influenced by the information about nanotechnology from various sources.

2. Theoretical Framework and Proposed Hypothesis

To examine how consumer's attitudes and perceived information affect their WTP for nano-packaged food products, the structural equation modeling is employed (Figure 1). The core of model is the relationship between WTP from experimental auction and three attitudinal constructs, TECHACCEPT, CONCERN, and GOVERNROLE. TECHACCEPT reflects consumer acceptance level for new technology in general, which corresponds to the positive statement from private industry. CONCERN is linked with the negative information from environmental agency and represents environmental and health concern caused by the application of nanotechnology in food packaging. GOVERNROLE indicates the importance of government role in restricting the use of nanotechnology in food products, which is parallel to a neutral statement referenced from governmental agency. In order to test and compare these relations under different information, we set up a three-round auction experiment with incremental information provided in each round. Besides, in light of pervious consumer researches on nanotechnology, we also measure the consumer attitudes towards prolonging shelf-life of food products (SHELFLIFE), and their trust in governmental regulation and certification of new technology (TRUST).

2.1. Preference for prolonging food shelf life (SHELFLIFE)

A product's shelf life is the period before the product becomes unacceptable for consumption from sensorial, nutritional or safety perspectives (Labuza & Fu, 1993). Shelf life is a critical attribute affecting consumer acceptance of a food product, and it serves as an anchor point (Lyndhurst, 2008) and a hidden control point (Wansink & Wright, 2006) when consumers evaluate food product quality. If a food product reaches its expiration date, consumers' purchase intention can greatly decrease even if its appearance, aroma and flavor are still acceptable (Lyndhurst, 2008).

In response to consumers' needs, various technologies have emerged in the past decades to prolong the shelf life of foods such as pasteurization, high-pressure processing, genetic modification and novel food packaging. Most of those technologies were accepted by consumers with only very few exceptions, e.g., food irradiation (Ronteltap, van Trijp, Renes, & Frewer, 2007). The proven effectiveness of prolonging product life has, in turn, increased consumer confidence in novel food technologies. Nano-package is by far regarded as the most effective food package to prolong shelf life (Henriette & Azeredo, 2009). It can be used as an oxygen barrier layer in the extrusion manufacturing of bottles for fruit juices, dairy foods, beer and carbonated drinks, or as nanocomposite layers in multilayer films to enhance the shelf life of a variety of foods such as processed meats, cheese, confectionery, cereals, and boil-in-bag foods (Moraru et al., 2003). Other shelf life enhancements can be achieved by incorporating nanoclay into plastic matrices to improve thermal resistance, or employing silver nanocomposites to improve antimicrobial effectivity (Damm, Münstedt, & Rösch, 2007).

Combining the controlling feature of shelf life amongst all food attributes, and the effectiveness of nano-package in prolonging food shelf life, we hypothesize that:

H1. *Consumers' preference for prolonging food shelf life positively relates to their acceptance of novel technologies employed in food products.*

Furthermore, given the effect of affect heuristics, consumers' preferences for longer shelf life may suppress their risk perceptions towards health and environment. Thus, we hypothesize that:

H2. *Consumers with stronger preference for improved shelf life are less concerned with the influence of nano-packaging on health and environment.*

2.2. Trust in Institution (TRUST)

Social trust, especially the trust of decision makers of technology management such as the Food and Drug Administration (FDA), is known to be a key element to predict consumer's WTP for food products produced using new technologies (Ronteltap, van Trijp, Renes, & Frewer, 2007). This trust is especially crucial for consumers when dealing with a new food technology that they have less knowledge of (Siegrist & Cvetkovich, 2000). As previous researches show that most people were not familiar with the term nanotechnology (Gaskell, Ten Eyck, Jackson, & Veltri, 2005), it is important to investigate the effect of trust in institutions on consumer attitudes toward nano-packaged food products.

The reliability of trust measurement has been proven by consumer research in the genetic modification technology. Frewer, Scholderer and Bredahl (2003) and Chen and Li (2007) stated that trust in institution is particularly important if consumers perceive they have no control over society's adoption of a new technology. Rodríguez-Entrena, Salazar-Ordóñez and Sayadi (2013) also concluded that consumer trust in institutions is positively related to their attitude toward GM foods. In other words, trust has an indirect impact on the acceptance of technology applications in food products (Siegrist, Cousin, Kastenholz, & Wiek, 2007).

It has been shown that higher trust in institutional regulation increases consumer confidence in restrictive governmental policies and reduces perceived uncertainty and risk (Ronteltap, van Trijp, Renes, & Frewer, 2007). Thus, we hypothesize the following two relationships:

H3. *More trust in institutional regulation on food technology reduces consumers' concern about the application of nanotechnology in food products.*

H4. *Trust in institutional regulation on food technology positively affects consumer attitude towards governmental role in technology restriction.*

2.3. General acceptance of new food technology (TECHACCEPT)

Consumers' awareness of nanotechnology is very low (Chaudhry et al., 2008; Siegrist, Stampfli, Kastenholz, & Keller, 2008; van Giesen, Fischer, van Dijk, & van Trijp, 2015), which is similar to genetic modification technology in its early stage. The majority of consumers are undecided or feel that they don't know enough to form a view. Under such circumstance, the level of comfort or ease of adopting new technology applications plays a significant role in the acceptance of nanotechnology (Silvestre, Duraccio, & Cimmino, 2011). When it comes to the food industry, consumers' attitudes are even more sensitive (Cushen, Kerry, Morris, Cruz-Romero, & Cummins, 2012). For example, several new food technologies in the past faced reluctant acceptance when they first appeared, such as canned food, pasteurized milk, microwave cooking and GM food (IFT, 2000). Recent studies show that similar pattern occurs in nanotechnology and consumers are hesitant to buy nano-food or nano-packaged food (Siegrist, Cousin, Kastenholz, & Wiek, 2007). However, the use of nanotechnology in packaging seems to be more acceptable than the use of nanotechnology in food (Siegrist, Stampfli, Kastenholz, & Keller, 2008).

Hence, given the fact that consumers are sensitive to new technology's application in food, we hypothesize:

> ***H5.*** *Consumers with higher acceptance of new technologies are willing to pay more for nano-packaged food products.*

2.4. Environmental and health concerns about nano-packaged food products (CONCERN)

While governmental organizations such as EFSA and FDA have acknowledged the beneficial aspects of nanotechnology, they also admitted the lack of knowledge about the effects of nanotechnology on human and environmental health (EFSA, 2009; FDA, 2007). Both concerns are expected to have significant influence on consumers' purchasing decision.

For environment, the production of nano-package will inevitably use nanoparticles on a large scale, which leads to possible particles' migration into water, air and soil and may cause undesired consequences to the environment (Silvestre, Duraccio, & Cimmino, 2011). Under such circumstances, more research is still needed on how long and in which form will the undesired nanoparticles survive. Existing study indicates that the expected nanoparticle concentrations in environment are substantially limited and present low level risk for biological system (Boxall, Tiede, & Chaudhry, 2007).

Besides the influence on environment, effect to human health such as nanoparticle migration into human body and binding nutrients could also be caused by the interactions between nanoparticles and existing chemicals, which is especially true for nanoparticles used in food packages (Chau, Wu, & Yen, 2007). More research has been focusing on the toxicity of materials at nano-level to human health, and show possible oxidative damage, inflammatory reactions and even signs of early tumor formation majorly due to the nanoparticles' ability to cross cellular barriers (Hoet, Brüske-Hohlfeld, & Salata, 2004; Nel, Xia, Madler, & Li, 2006; Carlson et al., 2008; Bouwmeester et al., 2009).

Combining both environmental and health concerns, we hypothesize that:

> ***H6.*** *The more environmental and health concerns consumers have about nano-packaging, the less they are willing to pay for nano–packaged food products.*

2.5. Reliance on governmental regulation (GOVERNMENT)

With the rapid development of nanotechnology's application in food industry, it is a great challenge to develop corresponding regulations. Successful governmental regulation could ensure the development and deployment of nanotechnology (Chau, Wu, & Yen, 2007).

In the past decade, many nanotechnology initiatives, commissions, or centers have been launched by governments of the United States, Europe, Japan, China and other countries around the globe (Chen, Weiss, & Shahidi, 2006). FDA was among the first governmental agencies that provided guidance documents for nanotechnology. The Nanotechnology Task Force Report released in 2007 provided governmental recommendations on what information industry needs to clarify in their nano-products, and how regulatory policy could assist the development of the technology with ensured safety. More recently, on June 24, 2014, FDA further issued one draft and three final guidance documents pertaining to the use of nanotechnology in regulated products.

Under the present situation, it is of great interest to investigate how the importance of government regulations to U.S. consumers affect their WTP for nano-packaged food products. Given this relationship is barely investigated by previous research, we hypothesize that:

H7. *The more important governmental regulations on nano-products to consumers, the less they are willing to pay for nano-packaged food products.*

3. Research Material and Methodology

Our research protocol was submitted to and approved by the Institutional Review Board of the university. The detailed experimental and analytical methods are explained in this section.

3.1. Auction Experiment

Incentive compatible experimental auction is a powerful tool to elicit accurate consumer WTP for goods and it has been used by researchers to investigate consumer WTP for various products (Harrison & Rutström, 2008; Umberger & Feuz, 2004).

The auction mechanism used in the experiment was the Becker-DeGroot-Marschak (BDM) mechanism (Becker, Morris, & Marschak, 1964). Each participant submits the price he or she is willing to pay to purchase the product. If the bid for auctioned good is equal to or higher than the randomly drawn market price, then the participant is required to buy the product. In this way, the auction mechanism is incentive compatible because bidders have no strategic incentive to bid above or below their true values. During the experiment, participants were explicitly made aware of the fact that bidding their true values was their best strategy.

3.2. Products

The products used in the auction are conventional and organic apple sauce (12 oz.), spinach salads (5 oz.), and roasted peanuts (12 oz.) in both regular package and nano-package. These three food products were chosen because they differed in their shelf lives: salad has a short shelf-life, apple sauce has a medium shelf life and peanuts have a long shelf-life. The label ‘Nano-

Silver Technology' with the logo 'Stays Fresh Longer' was used for nano-packages, which is the typical labeling information found on nano-containers currently on the market.

3.3. Auction Participants

The experiment was conducted in St. Paul, Minnesota in April 2012 over a period of two weeks. In total, 109 participants were recruited through an advertisement in 13 local newspapers that have wide readership in all the socio-economic classes in the Minneapolis and St. Paul metropolitan area. The advertisement specified that only the grocery shopper in a household can participate in the experiment. To avoid bias, nanotechnology was not mentioned in the advertisement. Out of the 106 participants, 7 were dropped because of uncompleted information and invariant survey question answers.

3.4. Auction Design

The experimental auction consisted of three rounds of bidding, each with six products (conventional and organic salad, apple sauce and peanut). We followed the research protocol to present products sequentially by Huffman, Rousu, Shogren and Tegene (2007) and Liaukonyte, Streletskaya, Kaiser and Rickard (2013). In the first round, participants submitted their bids for products that were not labeled as nano-packaged (plain-labeled), and no information was provided. In the second round and third round, all bidding items were labeled with 'Nano-Silver Technology' and 'Stays Fresh Longer.' In the second round, general information about nanotechnology from Roosen, Bieberstein, Marette, Blanchemanche and Vandermoere (2011) was provided, and participants submitted their bids after viewing the information. In the third round, three sets of detailed information on nanotechnology from private industry, environmental group and FDA were presented and participants were asked to submit bids for the third time.

The information form private industry is primarily positive, it states the potential applications of nanotechnology in food packaging and its advantages of prolonging shelf-life. The environmental group's information is quoted from Friends of the Earth, a well-known environmental protection group, and their statement is mainly negative, focusing on the harmful aspects of nanomaterials. Lastly, the FDA's information is neutral illustrating both the usefulness of nanotechnology for food industry and the uncertainty about the potential risks. The three sets of information in the third round are correspondingly related to the latent constructs of TECHACCEPT, CONCERN and GOVERNMENT in the SEM model, respectively. As such, we can estimate the relative dominant effect of each set of information on WTP. The details of each information are shown in Table 1.

3.5. Auction Procedure

The diagrammatic representation of the experimental flow is shown in Figure 2. The experiment was set up on a computer, which allowed for little interaction between the participants and the moderator, thus reducing potential errors caused by communications.

Upon arrival to experiment lab, participants were asked to sign a consent form. They were then instructed on how to use the computer and mouse to traverse from one screen to another, and entering the bids on the bidding sheet. Participants were informed that the exact same real products shown in the image were being auctioned and if a participant won the auction, he/she would receive the item and pay the market price. Before the formal auction started, there was a practice round with a candy bar to help participant familiarize with the auction procedure. Then in the third round of bidding, as three sets of information (positive, negative and neutral) need to be provided sequentially on computer screens, we randomized the display sequence to control any possible order effects. Table 2 shows the randomized sequences and the number of participants in each sequence during the experiment. After three rounds of bidding, we randomly drew the binding round and binding product. If a participant's bid for the binding product in the binding round is higher than its randomly drawn market price, she/he was required to purchase the product by paying the market price. Finally, after the auction procedure, participants were required to complete a post-experiment survey about their opinions and general preferences corresponding to our proposed latent constructs, along with typical socio-demographic questions.

3.6. Structural Equation Model

Our conceptual framework and hypotheses were tested by Structural Equation Model (SEM) (Hair, Black, Babin, Anderson, & Tatham, 2006), it is a multivariate technique that allows for the simultaneous estimation of a series of separate, but interdependent relationships between latent constructs (Bagozzi, 1994). Those latent constructs cannot be observed directly, and SEM is used to relate consumers' WTP to their general attitudes, concerns and social beliefs.

The standard SEM consists of two parts, namely, the measurement model specifying the relationships between the latent variables and their constituent observed variables, and the structural model estimating the causal relationships between the latent variables (Toma, McVittie, Hubbard, & Stott, 2011). Given ξ being a vector of exogenous latent construct and η being a vector of endogenous latent construct, the relationship between a latent construct and its observed variables can be represented by a measurement model:

$$x = \mathbf{\Lambda}_x \xi + \delta \quad (1)$$

$$y = \mathbf{\Lambda}_y \eta + \varepsilon \quad (2)$$

where x and y are vectors of observed variables for the exogenous and endogenous latent constructs (ξ and η), respectively, $\mathbf{\Lambda}_x$ and $\mathbf{\Lambda}_y$ are matrices of coefficients relating the constructs

ξ and η to observed variables x and y, and δ and ε are the measurement error. Further into the relationships between the latent constructs, it can be represented as

$$\eta = \mathbf{\Gamma}\xi + \mathbf{B}\eta + \epsilon \tag{3}$$

where $\mathbf{\Gamma}$ is a matrix of coefficients relating the exogenous to the endogenous latent constructs, and $\mathbf{B}$ is a matrix of coefficients of the endogenous latent constructs in the structural model, ϵ is a vector of error.

In order to estimate the model parameters (represented by $\boldsymbol{\theta}$), we minimize the discrepancy between the estimated covariance matrix $\widehat{\mathbf{\Sigma}} = \mathbf{\Sigma}(\widehat{\boldsymbol{\theta}})$ and the observed sample covariance matrix $\boldsymbol{S}$. Using the AMOS 21.0 (Arbuckle, 2013) software package and maximum likelihood (ML) method, the discrepancy minimization function is defined as

$$F_{\mathrm{ML}}(\boldsymbol{S}, \mathbf{\Sigma}) = \mathrm{tr}(\boldsymbol{S}\mathbf{\Sigma}^{-1}) - \log|\boldsymbol{S}\mathbf{\Sigma}^{-1}| - k \tag{4}$$

where $|\cdot|$ represents the determinant of matrixes, 'tr' indicates the trace and k is the total number of stochastic variables. Then the ML estimator of $\boldsymbol{\theta}$, is defined by

$$\hat{\theta} = \arg\ \min_{\theta} F_{\mathrm{ML}}(\boldsymbol{S}, \mathbf{\Sigma}) \tag{5}$$

Next, we conducted several statistical tests for the goodness-of-fit of the measurement and structural model: normed chi-square fit test (χ^2) measures whether the predicted and the actual covariance matrix are identical, it is calculated by dividing the chi-square value (which is sensitive to the sample size) by the number of degrees of freedom. According to Arbuckle (2013), the goodness-of-fit is acceptable when normed chi-square is less than 5, and the more conservative acceptable thresholds are between 1 and 3. The root mean square error of approximation (RMSEA) measures the discrepancy between the observed and estimated covariance matrix, and is recommended to be less than 0.10 (Hu & Bentler, 1999). Goodness-of-fit index (GFI) and Comparative fit index (CFI) are derived from a comparison of the hypothesized model and the independent model. GFI indicates the overall percentage of observed covariance explained by the estimated covariance and CFI is based on the relative comparison of the fit of the proposed model to the fit of the null model. Both are acceptable when they are between 0.90 and 1 (Van Ittersum, Meulenberg, Van Trijp, & Candel, 2007). Finally, Tucker-Lewis non-normed fit index (TLI) is an index that is similar to CFI and it is suggested to be greater than 0.90 (Bentler, 1990).

4. Analysis Results

4.1. Demographics and bidding average

Table 3 summarizes the socio-demographics information of participants. The average age of participants was 54, the average household income was $61,432 dollars and the average household size was 2.47 people per household. Seventy-three percent of our participants were women, 57% of them had at least a college degree and 56% of them were married. It was also reported that 67% of the sample had a job and 24% of the sample were retired. Compared to the US census data, our sample has a higher percentage of female. This is due to the fact that women are more likely to be responsible for shopping than men in a household.

The average WTP results and the percentage changes between different rounds are reported in Table 4. According to the mean WTP, both conventional and organic peanuts received the highest average WTP, followed by salad, and the average WTP for apple sauce was the lowest. Comparing between conventional and organic products, all organic products had significantly higher average WTP. Comparing the change of WTP across different rounds, participants' WTP increased from round 1 to round 2, when the general information about nanotechnology and nano-labeled products were presented. After given the detailed information from three sources in round 3, participants' average WTP decreased by approximately 10%. The average WTP for plain-labeled products in round 1 and the average WTP of nano-packaged products in round 3 were similar for all products except for conventional apple sauce (increased by 15%).

4.2. Measurement Statistics

The questions used to generate the latent constructs are reported in Table 5. Preference for prolonging food shelf-life (SHELFLIFE) and trust in institution (TRUST) were measured by three Likert-scale questions. General acceptance of new food technology (TECHACCEPT), environmental and health concerns toward nanotechnology food packaging (CONCERN) and reliance toward government regulation (GOVERNMENT) were measured by four questions. To test the reliability of each latent construct, Cronbach's alpha values were calculated and reported in Table 5. Because of the diversity of questions used for generating SHELFLIFE and GOVERNMENT, their Cronbach's alpha were lower compared to other three constructs. In addition, the WTP constructs yielded satisfactory Cronbach's alpha of 0.85, 0.92 and 0.94 for round 1, 2, and 3, respectively, representing reasonable reliability of the constructs (Nunnally & Gernstein, 1978). Furthermore, in order to examine the convergent and discriminant validities of the measurement model, the model fit statistics (Normed χ^2, p value, RMSEA, GFI, CFI, and TLI) were estimated and reported in Table 6. Most statistics suggest that the model fit the data reasonably well (e.g., TLI: 0.92-0.95, RMSEA: 0.05-0.06), except GFI estimates (0.80) were lower than the normal threshold, which might occur when having relatively smaller number of (<250) participants.

Next, the complete structural equation model, shown in Figure 3, was estimated for each auction round. During the estimation, the errors of indicators for WTP construct (average WTP for each product) were allowed to correlate to ensure the model fit (additional analysis revealed that conclusions were not affected without correlating the WTPs). According to Table 6, the fit of the complete model was reasonable (e.g. for round 2, $\mathrm{RMSEA} = 0.06, \mathrm{GFI} = 0.80, \mathrm{CFI} = 0.95, \mathrm{TLI} = 0.94$). While the measurement statistics for each round were acceptable in all three rounds, the statistics improved from round 1 to round 3.

4.3. Model Estimates

The estimated coefficient, standard error, along with standardized coefficient of the causal relationships between latent construct are reported in Table 7.

Due to the fact that only WTP constructs vary across the three rounds of auction, the results for hypothesis H1 to H4 were consistent across the three rounds. Those hypotheses were statistically supported as follows: while participants' preference for prolonging food shelf-life (SHELFLIFE) increased their general acceptance of new food technology (TECHACCEPT), it reduced their environment and health concerns toward nanotechnology food packaging (CONCERN); the level of trust in institution (TRUST) had significantly positive impact on both environmental and health concern about nanotechnology food packaging (CONCERN) and reliance toward government regulation (GOVERNMENT).

The causal relationships tested in H5 to H7, as the major hypotheses we are testing, varied by auction rounds. For H5, the acceptance level of new food technology had insignificant effect on WTP in round 1 (when bidding for products with that are not labeled as nano-packaged and no information was provided) and round 3 (when bidding for nano-packaged products after both general and detailed information were provided). However, in round 2 when only general information about nanotechnology was presented, the general food technology acceptance had significant positive effect on the WTP for nano-packaged products. Also, in round 2, TECHACCEPT served as a mediator between SHELFLIFE and WTP, indicating people's preference for longer shelf-life indirectly increased their WTP for nano-packaged products.

For H6, the causal relationship between concern about nanotechnology and WTP was not statistically significant in the first round. However, starting the second round, results showed that the level of environmental and health concerns significantly decreased participants' WTP, and this negative relationship was even more evident in round 3 when participants received both the general and detailed information about nanotechnology. Again, considering round 2 and 3, CONCERN acted as the mediator between WTP and SHELFLIFE/TRUST, which established two indirect relationships: stronger preference for prolonging shelf-life decreased the environmental and health concerns about nano-packages and led to an increase in WTP for nano-packaged food; and stronger trust in institutions increased participants' environmental and health concerns about nano-packages and thus decreased their WTP.

For H7, in round 1, the supportiveness of government regulation restricting the use of nanotechnology directly led to a decrease in the WTP for the food products without nano-package labels. Interestingly, this negative effect diminished for nano-packaged food products in round 2 and 3. A possible explanation is that the relationship tested in H7 is diluted by the dominance effect of other constructs (CONCERN and TECHACCEPT) after participants received the information. Nevertheless, in round 1, trust in institution (e.g. FDA) indirectly decreased the WTP for food products with plain labels.

5. Discussion

Several implications can be drawn from the SEM model results. First, in round 1, the only supported hypothesis was H7. Consumers with higher reliance on government regulations were willing to pay less for plain-labeled food products. It is possibly because cautious consumers pay more attention on labeling information when make purchases, and especially government issued labels (e.g. USDA organic). Since the experimental products in round 1 were plain-labeled, the more reliance participants had on governmental regulations, the lower participants' WTP for the plain-labeled products. This implication is consistent with the previous findings that cautious consumers who seek government issued labels are more aware of and concern about their wellbeing by engaging in behaviors that maintain a good state of health (Michaelidou & Hassan, 2010). In this case, they might relate the missing label information with potential negative outcomes.

The study also suggests that for nano-packaged food products, general information about nanotechnology triggers technology accepters' higher WTP (H5). This is a straightforward relationship, according to survey response, technology accepters 1) were less skeptical about new technologies, 2) did not intend to avoid new technologies, 3) preferred to be the first to try new technologies, and 4) would not wait until a technology is proven to be safe before adopting. However, general information about nano-technology dampened participants' purchase intention if they had more environmental and health concerns (H6), possibly because of the negative statement made in the general information that 'there is uncertainty regarding how nano-materials may interact with human health and the environment.' It has been proved by previous studies that information on potential health and environmental risks significantly decreases consumer WTP for technological modified products (Roosen, Bieberstein, Marette, Blanchemanche, & Vandermoere, 2011; Ronteltap, van Trijp, Renes, & Frewer, 2007). This is especially true for food products and consumers' concern about food hazards are important determinants of their acceptance (Frewer et al., 2011; Miles & Frewer, 2001). Furthermore, nano-packaged food products along with general information decreased the participants' reliance on governmental regulation (H7), partially led by the dominant effects from technology acceptance and environmental and health concerns.

After giving the specific and detailed information of nanotechnology from private industry (positive), environmental agency (negative), and government (neutral), the average WTP decreased compared to that when only general information was provided. This reduction was majorly contributed by the negative statement from the environmental group. According to the estimation, the effect of environmental and health concern became the only significant construct that impacted WTP (H6) in round 3. Aligned with the 10% decrease in WTP in round 2, we can conclude that once consumers have comprehensive understandings about nanotechnology application in food, the inevitable concern about environment and health will lead to a significant reduction in their WTP for nano-packaged food products. Similar results have also been proven by previous studies. Roosen, Bieberstein, Marette, Blanchemanche and Vandermoere (2011) studied consumer WTP for food produced with nanotechnology using information on health, society and environment, and their study revealed that when all information is given, health information dominates and significantly decreases WTP. Macoubrie (2006) investigated various public concerns about nanotechnology, and found that 'long-term health effects' and 'environmental footprint' were the two dominant concerns. Most recently, Yue, Zhao and Kuzma (2015) found that consumer may not reject nano-food outright as long as safety is ensured.

Finally, shelf-life, as the major benefit of nano-packaging, had a significant indirect effect on consumers' WTP. In round 2, after general information was provided, participants were willing to pay a significant price premium on nano-packaged food products compared to plain-labeled food products in round 1. Given that the general information about nanotechnology was neutral, we can conclude that this price premium was largely contributed by the benefits that nano-package can prolong shelf life of food products. In addition, based on the SEM estimation results, the more participants cared about prolonging product shelf-life, the more acceptance they had toward general food technologies (H1) and the less they were concerned about environmental and health risks caused by nano-package (H2). Thus, both the higher level of acceptance for new technology and the lower level of concern about environment and health passed on to an increase in consumer WTP (H5 and H6).

6. Conclusions and Implications

This study employs SEM to estimate experimental auction data to examine the major factors that influence public acceptance of nano-packaged food products, and investigates the effect of information on consumer WTP. Three rounds of auction were conducted with more information given in each round, and seven hypotheses were tested.

Three implications can be drawn from our estimation results. First, from the standpoint of policy makers, and learning from the past genetic modification debates, the ignorance of health and environmental concerns may hinder public acceptance of new food technology. Thus, it is extremely important to implement adequate regulations to ensure the safety standard of nanotechnology's application in food products.

Second, learning from the experience with GM food, it is also important to take public preferences of nanotechnology into account at the early stage of commercialization. Our results show that consumers' WTP for nano-packaged food products are not influenced by the level of reliance on government regulation, but affected by their attitude towards new technology and associated environmental/health concern. Therefore, during the process of designing regulatory standards for nanotechnology's application in the food industry, it is crucial to ensure the transparency of any decision-making process by increasing communication with consumers in early stages. Our result proved, again, that the formation of public response to emerging technologies is an integral part of developing a successful research and governance strategy with regard to such technologies (Ward & Barnes, 2001).

Lastly, in order to achieve the market success for nano-packaged food products, appropriate labeling and pricing strategy should be adopted. In our study, after gaining general information about nanotechnology, participants were willing to pay more for nano-packaged food products with the label indicating longer shelf-life compared to the plain-labeled food products. But once participants read detailed information about nanotechnology's application in food, the price they were willing to pay for nano-packaged products decreased. Therefore, though it is preferable for food products to have prolonged shelf-life with nano-package, right labeling information and acceptable price ranges are also determinant factors in consumer acceptance.

As a result of these implications, public acceptance of nano-packaged food products will be largely dependent upon how transparent the industry is and how the government can protect them from uncertain hazards. Aligned with Duncan (2011), industry and government's openness regarding what they're doing and why they're doing it regarding nanotechnology will go a long way toward assuaging public fears about nano-packaged food products.

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Table 1. Information from various sources displayed to the participants.

Source	Information presented
Round 2	
General information	Nanotechnology refers to materials, systems and processes which exist or operate at the scale of atoms and molecules. This is a scale between 1 and 100 nanometres (nm). One nanometre is one millionth of a millimeter (mm). Materials at the nano-scale show novel properties that lead to novel applications in diverse fields like medicine, cosmetics, biotechnology, energy production and environmental science. There is uncertainty regarding how nano-materials may interact with human health and the environment. Nanotechnology offers new opportunities for food industry application. Manufactured nano- materials are already used in some food products, nutritional supplements and food-packaging applications(Bieberstein et. al., 2013; Roosen, Bieberstein, Marette, Blanchemanche, & Vandermoere, 2011).
Round 3	
Private Industry (Positive)	Nano-packaging has created a modified atmosphere in packaging in order to control the flow of gases resulting in improving the shelf-life of products like vegetables and fruits. One of the most promising innovations in smart packaging is the use of nanotechnology to develop antimicrobial packaging. Scientists at big name companies including Kraft, Bayer and Kodak, as well as numerous smaller companies, are developing a range of smart packaging materials that will absorb oxygen, detect food pathogens, and alert consumers to spoiled food. These smart packages, which will be able to detect public health pathogens such as Salmonella and E. coli. (Nanobio-RAISE project, 2011)
Environmental Agency (Negative)	Anti-bacterial nanofood packaging and nano-sensor technologies have been promoted as delivering greater food safety by detecting or eliminating bacterial and toxin contamination of food. However it is possible that nanomaterials (such as silver, zinc oxide and titanium dioxide) will migrate from antibacterial food packaging into foods, presenting new health risks. This appears inevitable where nano-films or packaging are designed to release antibacterial onto the food surface in response to detected growth of bacteria, fungi or mould. Silver nanoparticles are found in an increasing number of consumer products such as food packaging, odor resistant textiles, household appliances and medical devices. The potential for nanosilver to adversely affect beneficial bacteria in the environment, especially in soil and water, is of particular concern. Conversely, there is also a risk that use of silver nanoparticles (“nanosilver”) will lead to the development of antibiotic resistance among harmful bacteria. (Miller, Lowrey, & Senjen, 2008).
Governmental Agency (Neutral)	Nano-packaging has the potential to help improve the safety, shelf-life, and convenience of food. At present there is insufficient data publicly available to reach meaningful conclusions on the potential toxicity of food or color additives incorporating nano-materials, although the available information does not give us cause for concern. (FDA, 2007)

Table 2. Six different sequences of the information presented to the participants

Sequence	First Information	Second Information	Third Information	No. of participants.
1	Private Industry	Environmental Group	Government	17
2.	Private Industry	Government	Environmental Group	21
3.	Government	Private Industry	Environmental Group	16
4.	Government	Environmental Group	Private Industry	17
5.	Environmental Group	Government	Private Industry	17
6.	Environmental Group	Private Industry	Government	17

Table 3. Summary statistics of respondents' socio-demographic backgrounds

Characteristics	Description	Mean	Standard Deviation
Gender	1 if female, 0 if male	0.73	0.44
Age	Age of participants at the time of auction	54.09	15.47
Annual Income	Participants' annual income in USD	61432	27978
Education	1 if college graudate or higher, 0 otherwise	0.57	0.49
Marital Status	1 if married, 0 if single	0.56	0.49
Household Size	Number of people in the household	2.47	1.53

Table 4. Summary statistics for bids by round

	Apple Sauce	Organic Apple Sauce	Peanut	Organic Peanut	Salad	Organic Salad
Mean WTPs						
Round 1	1.43	1.89	2.00	2.51	1.65	2.15
Round 2	1.78	2.17	2.18	2.59	1.92	2.31
Round 3	1.65	1.96	2.00	2.32	1.71	2.06
WTP change						
Round 1 – 2	24.48%	14.81%	9.00%	3.19%	16.36%	7.44%
Round 2 – 3	-7.30%	-9.68%	-8.26%	-10.42%	-10.94%	-10.82%
Round 1 – 3	15.38%	3.70%	0.00%	-7.57%	3.64%	-4.19%

Table 5. The observed indicators for latent constructs and the Crobach's Alpha

Latent Construct	Observed Indicators	Scale	Alpha
Preference for prolonging food shelf-life (SHELFLIFE)	x_1: Nanotechnology would help me buy in bulk and save money because the food would last longer. x_2: Products have expiration dates, extending the longevity is necessary to me. x_3: I would be very interested in nanotechnology packaging if it greatly extended the shelf life of a highly perishable product (e.g. salad mix).	1 = strongly disagree 5 = strongly agree	0.64
Trust in Institution (TRUST)	x_4: Governmental (e.g. FDA) regulation and certification of new technology is important to me if it is a component of the food (x_1). x_5: Governmental (e.g. FDA) regulation and certification of new technology is important to me if the technology is in contact with the food (such as packaging). x_6: Governmental (e.g. FDA) regulation and certification of new technology is important to me if it is used in the preparation / processing of the food products.	1 = strongly disagree 5 = strongly agree	0.91
General acceptance of new food technology (TECHACCEPT)	y_1: I am skeptical about adopting new technologies, because in the past some of them have proven risky for the health. y_2: New technologies in food scare me, so I avoid them. y_3: I do not want to be the first to try a new technology. y_4: I would wait until a technology is proven to be safe before I adopt it.	1 = strongly agree 5 = strongly disagree	0.74
Environmental and health concerns toward nanotechnology food packaging (CONCERN)	y_5: Nano-particles leaching into the food. y_6: Impact on health. y_7: Impact on environment. y_8: Lack of research on the long-term effects.	1 = not concerned 5 = extremely concerned	0.88
Reliance toward government regulation (GOVERNMENT)	y_9: Governmental policies restricting the use of nanotechnology in food production are good for the human health. y_{10}: The government should carefully monitor the correct use of Nanotechnology in the medical, agricultural and food sectors. y_{11}: FDA approval is important to me. y_{12}: The government should establish a regulatory system to regulate nanotechnology, like what is now done for biotechnology.	1 = strongly disagree 5 = strongly agree	0.67

Table 6. Goodness-of-fit indices

	Normed χ^2	p	RMSEA	GFI	CFI	TLI
Measurement Model						
Round 1	1.37	0.00	0.06	0.81	0.93	0.92
Round 2	1.28	0.00	0.05	0.81	0.95	0.95
Round 3	1.26	0.00	0.05	0.82	0.96	0.95
Sturctural Model						
Round 1	1.41	0.00	0.07	0.80	0.92	0.91
Round 2	1.33	0.00	0.06	0.80	0.95	0.94
Round 3	1.32	0.00	0.06	0.80	0.95	0.94

Talbe 7. SEM estimation results for each bidding round

	Coefficient (S.E.)			Standardized Coefficient		
	Round 1	Round 2	Round 3	Round 1	Round2	Round 3
H7: GOVERNROLE → WTP	**-0.14*** [a] **(0.08)**	0.12 (0.09)	0.03 (0.09)	-0.10	0.06	0.02
H6: CONCERN → WTP	-0.01 (0.04)	**-0.25** (0.12)**	**-0.31** (0.15)**	0.01	-0.12	-0.15
H5: TECHACCEPT → WTP	-0.05 (0.04)	**0.15* (0.08)**	0.09 (0.07)	-0.05	0.10	0.06
H4: TRUST → GOVERNROLE	**0.48*** (0.10)**	**0.46*** (0.10)**	**0.47*** (0.10)**	0.58	0.54	0.56
H3: TRUST → CONCERN	**0.25** (0.09)**	**0.25** (0.09)**	**0.25** (0.09)**	0.32	0.33	0.32
H2: SHELFLIFE → CONCERN	**-0.29** (0.14)**	**-0.29** (0.14)**	**-0.29** (0.14)**	-0.25	-0.25	-0.26
H1: SHELFLIFE → TECHACCEPT	**0.90*** (0.28)**	**0.89*** (0.28)**	**0.92*** (0.28)**	0.53	0.54	0.54

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

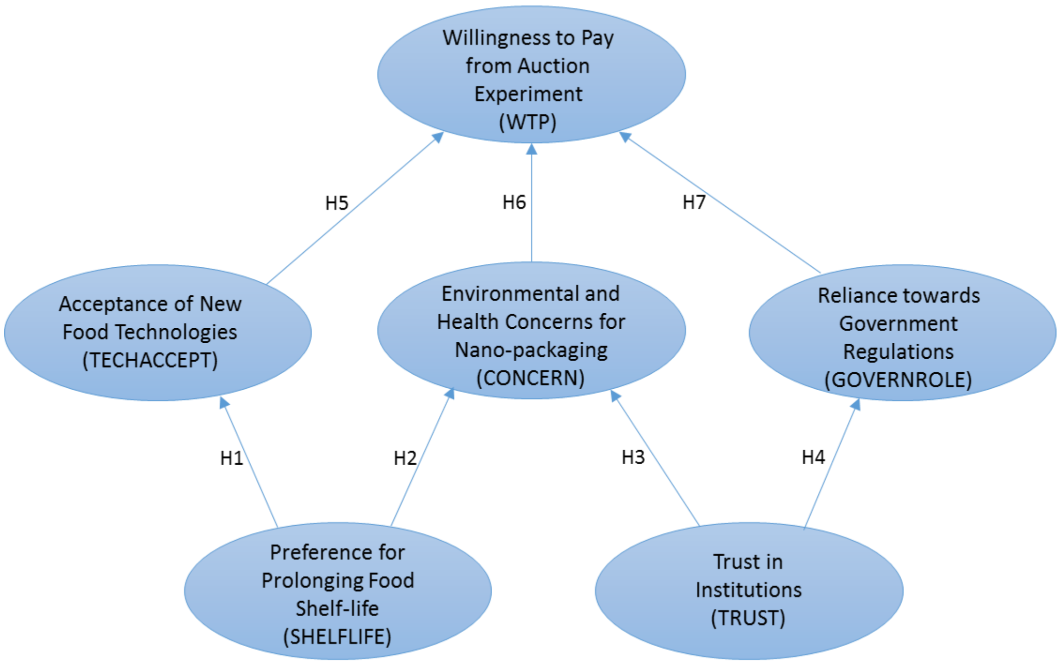


Figure 1. Conceptual framework

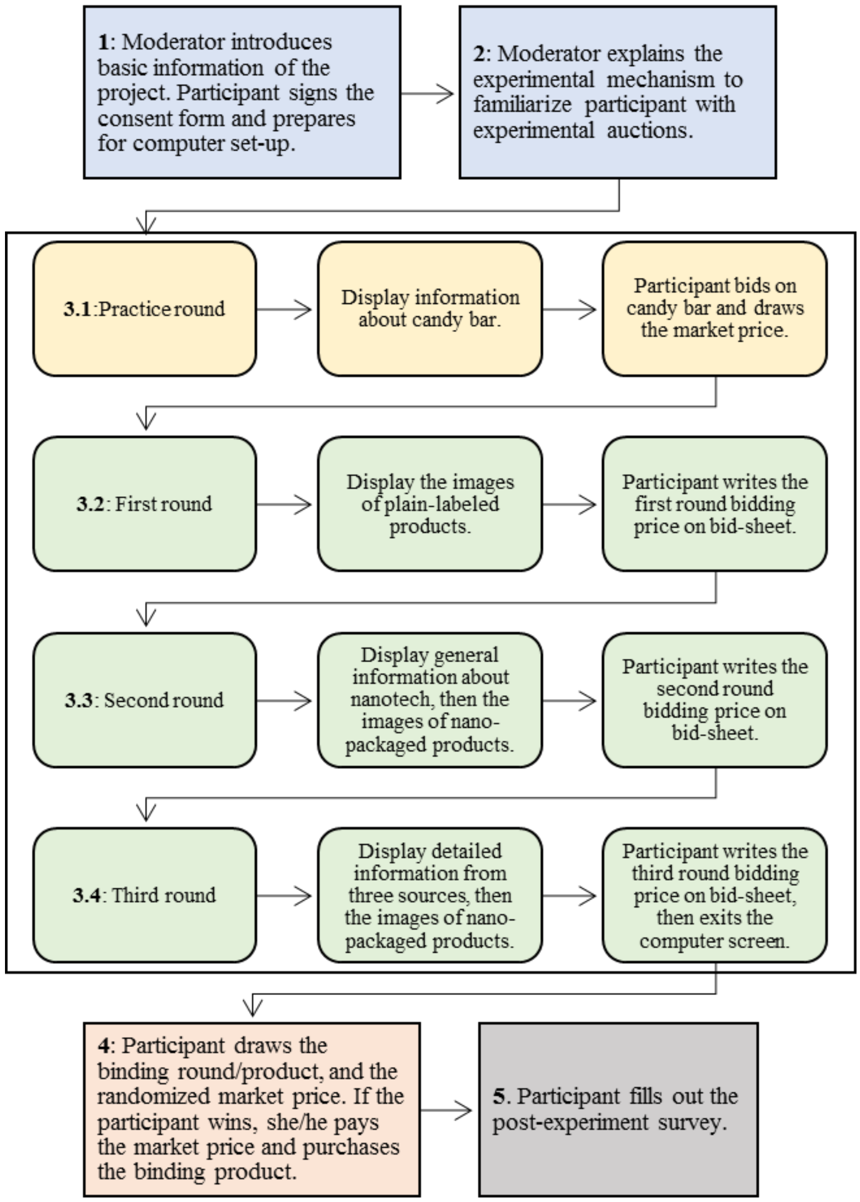
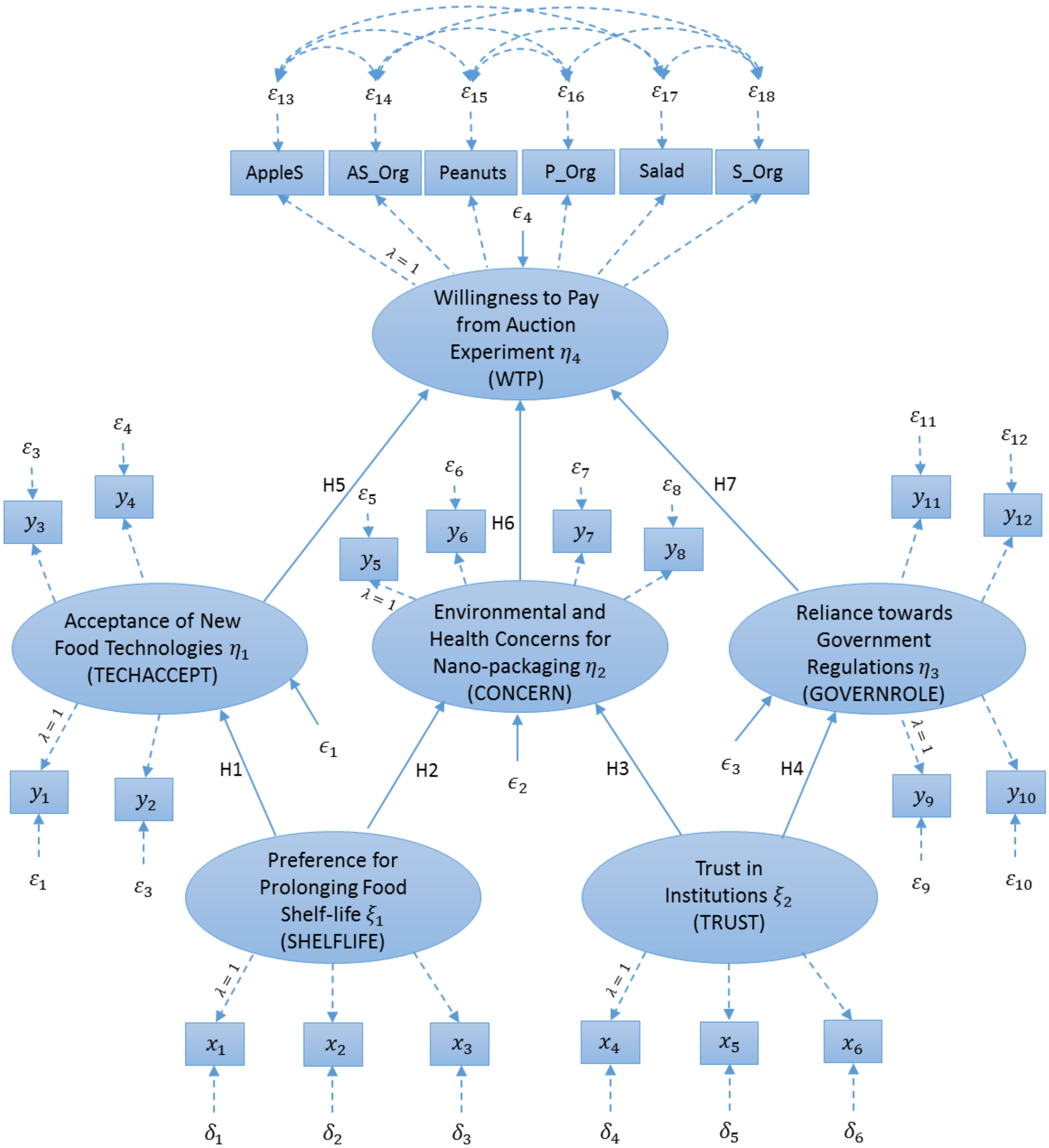


Figure 2. Experimental flow for the experimental auctions



Notes: The terms in ellipses represent latent constructs, and those in rectangles represent observed variables. The solid arrows represent structural equations (i.e. cause-and-effect relationships), and the dashed arrows represent measurement equations (relationships between observed variables and the latent constructs). To assign a fixed unit of measurement to the latent constructs, one of the λ's representing the relationships between the observed variables and a latent construct is normalized to one.

Figure 3. Complete SEM model