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NANOTECHNOLOGY IN THE FOOD SYSTEM: CONSUMER ACCEPTANCE AND WILLINGNESS TO PAY

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NANOTECHNOLOGY IN THE FOOD SYSTEM: CONSUMER ACCEPTANCE AND WILLINGNESS TO PAY

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Agriculture at the University of Kentucky

By
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ABSTRACT OF DISSERTATION

NANOTECHNOLOGY IN THE FOOD SYSTEM: CONSUMER ACCEPTANCE AND WILLINGNESS TO PAY

Nanotechnology is one of the key innovative technologies in the present century. The food industry has applied this technology in each of its sectors. Nanotechnology has tremendous potential in food and agriculture, including advancing agricultural cultivation and food production, enhancing food nutrition and flavor, and improving food packaging and preservation. However, the novel properties of nanoscale materials that allow beneficial applications are also accompanied with uncertainties, even unknown risks. A number of studies have examined public understanding and acceptance of nanotechnology via surveys in both the US and Europe. However, most of these studies concentrated on public attitudes in general. Few works focused on specific products, let alone food or food related products.

This project will contribute to the literature by calculating monetary valuations (i.e., willingness-to-pay) for canola oil where new techniques are utilized. Using choice experiment survey data, consumers' valuations for nano attributes were estimated with choice models. As implied, consumers were willing to pay $0.95 less for a typical bottle (48 fl. oz.) of canola oil if it was produced from nanoscale-modified seed; $0.51 less if the final products were packed with nanotechnology-enhanced packaging technique; and no significant difference was found for oil that was designed with health enhancing nano-engineered oil drops, which would require interaction with the human digestive system.

Additionally, the results revealed unobserved heterogeneities among respondents in their willingness-to-pay for canola oil attributes. Aligned with descriptive results, 46.7% of the respondents reported that they were optimistic about new technology applied to food products. While a significant portion of the respondents (42.8%) indicated that they might gain benefits at the same level as risks, there were a slightly larger proportion of the respondents who feared they might be exposed to more risks than benefits through nanofoods. Further analysis included respondents' attitudes and opinions as well as theirdemographic and socioeconomic characteristics toward the goal of understanding the underlying behavior difference. Findings from this study will help bridge the gap between scientific innovation and public policy and social-economic concerns.

Implications for government policy that can be efficiently used to monitor and regulate these technologies were also investigated.

KEYWORDS: Willingness to Pay, Choice Experiment, Nanotechnology Application, Mixed Logit Model, Risk and Benefit Perception

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Dedicated to my family, especially to my parents
-- Linfang Zhou and Yinping Ai,
my sister Xuanzhen Zhou, and my brother Gumin Zhou
for their ultimate loves, supports and encouragements

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Nanotechnology in the Food System: Consumer Acceptance and Willingness to Pay

Chapter 1 Introduction

1.1. Nanotechnology 101

1.1.1. Definition and background

Nanotechnology is science, engineering, and technology conducted at the nanoscale. The prefix “nano” is a Greek word meaning “dwarf” or “small”. It is primarily used in the metric system denoting a factor of 10^{-9} or a billionth and was officially confirmed as standard in 1960. A nanometer is thus one billionth of a meter. The mostly adopted definition of nanotechnology is provided by the world’s largest funder of nanotechnology research: National Nanotechnology Initiative (hereinafter, NNI[1]). It defines nanotechnology as: “the understanding and controlling of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications not feasible when working with bulk materials or even with single atoms or molecules. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling and manipulating matter at this length scale” (NNI, 2008).

However, nanoscale particles are not new in either nature or science. Many important functions of living organism in human bodies and animals actually take place at the nanoscale. For example, a typical protein such as hemoglobin, which carries oxygen through the bloodstream, is about 5 nanometers in diameter. Other nanomaterials surrounding us include smoke from fire, volcanic ash, sea spray, as well as products resulting from burning or combustion process (NNI, 2008). In the scientific area, nanomaterial has been used back to the ancient Egypt and Rome in the 10^{th} century, where a nanomaterial, a nanoscale gold, was used to color stained glasses and ceramics (Daniel and Astruc, 2004). Recent advances in areas such as microscopy have given scientists more new tools to understand and take advantage of phenomena that occur naturally when matter is organized at the nanoscale (NNI, 2010).

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[1] National Nanotechnology Initiative, NNI: www.nano.gov

1.1.2. Promising Applications in general

Nanotechnology is developing rapidly in the current age and attracts attention to the opportunities brought out from the small packages in the nanoscale. Governmental investment from all around the world increased over $50 billion (ETC, 2010), which is $10 billion on average each year. President Obama's Budget for Fiscal Year 2012 provided $2.1 billion for the National Nanotechnology Initiative (NNI), an increase of $201 million compared to the 2010 NNI level (NNI, 2012). With the billions that have been and will be put into R&D for nanotechnology, the outcomes are expected to be promising.

This new technology is projected to have impact measured at least $1 trillion across the global economy by 2020. Nanotechnology industries worldwide would require at least 6 million workers by the end of the decade (Roco, et al., 2010). The Project on Emerging Nanotechnologies (PEN) was established in April 2005 by both the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts, who collaborates with researchers, governments, industries, NGOs, policymakers, and others to provide knowledge and analysis of the development and commercialization of nanotechnologies. The PEN complies and publishes an online inventory of nanotechnology-based consumer products marketed worldwide on an ongoing basis. As of March 10th, 2011, the inventory contains 1,317 products or product lines, a fivefold growth from 212 to 1,317 products since 2006 (PEN, 2011). The worldwide categories were distributed as: Health and Fitness (738), Home and Garden (209), Automotive, **Food and Beverage (105),** Cross cutting, Electronic and Computer, Appliance, Goods for Children (30). Products with relevance to multiple categories have been accounted for multiple times.

1.1.3. Growing Application in the Food System

In addition to applications in general areas, nanoscience is also inspiring science in the fields of food and food related products. It roots from the concepts that this technology provides a sound framework for developing an understanding of the interactions and assembly behavior of food components into microstructure, which influence food structure, rheology and functional properties at the macroscopic scale (Sangunsri and

Augustin, 2006). Nanomaterials in foods can be naturally occurring, as well as be purposefully added or manipulated. Nanoscale particles could be found in milk, such as casein micelles and whey proteins lactose, whose dimensions range from 0.5 to 300 nm. They are natural nanomaterials (Tuinier and Kruif, 2002). The muscle in meat and fish, and pectin in fruit also represent complex and highly organized nanostructure (Magnuson, et al., 2011). Many studies in food science indicate that the structure and function of naturally occurring nanomaterials in foods could be modeled to develop novel and beneficial applications, referred as to intentionally added nanomaterials. Examples include the self-assembling properties of casein micelles in milk for encapsulating agents, viscosifiers, and coatings (Graveland-Bikker, et al., 2006) and the nanostructure of meat and fish proteins for alternative, non-animal protein sources (Yang, et al., 2007).

In the beginning of the 21st century, the food industry had already adopted nanotechnology. For instance, the leading brand Kraft Foods in year 2000 established a NanoteK Research Consortium of 15 universities and national research laboratories to conduct research in nanotech for potential food applications (Watkins, 2003). A nationwide workshop was held later that year in Washington DC discussing the potential for nanotechnology to revolutionize agricultural and food systems (Rutzke, 2002). This workshop was the first and the roadmap of future nanoscience development. Amongst the topics discussed in the workshop were: nanosensors for improving food security, nanodevices for tracking food supply chain, and the development of smart delivery.

Today, nanotechnologies are impacting the food system since new techniques are being adopted into every sector of agriculture: from seed growth, to production, to fertilization, and to output delivery. For example, controlled environment agriculture (CEA) helps reduce agricultural waste and environmental pollution (Joseph and Morrison, 2006); nanosensors have been widely used in production to monitor soil conditions and crop growth (Millman, 2004), as well as to identify expiration day and provide reminders for new purchase orders. Table 1.1 presents a summary of current and potential applications of nanotechnologies in food and food related products. It was published by the USDA Economics Research Service researcher Jean Buzby (2010).

Table1.1 Examples of Current and Potential Food Applications of Nanotechnology

Applications Already Commercialized

- Nanosilver is incorporated in food cutting boards, cleaning sprays, kitchenware, food storage containers and refrigerator compartments for its antimicrobial properties (PEN Inventory 2009).
- Nanoparticles in nanoceuticals and nutritional supplements, such as colloids of zinc nanoparticles and other nano-sized minerals, and nano-encapsulates are on the market with claims of having enhanced uptake and/or targeted delivery of content (Bouwmeester, et al., 2009) PEN Inventory 2009).
- Nanoparticles such as nanoclays are incorporated into plastic beer bottles to increase strength, make them more shatter proof, and extend shelf life by acting as a barrier to keep oxygen outside the bottle and carbon dioxide inside (PEN Inventory 2009).
- Nanochips or nanosensors are commercially used to detect storage conditions conducive to spoilage (e.g., temperature or moisture problems) (Bouwmeester, et al., 2009). For example, nanosensors are used on food pallets during transport in refrigerated trucks to detect temperature violations.

Applications Proven in Concept but not yet Commercialized

- Non-nanotechnology biosensors are currently commercially available for detecting E. coli O157, Campylobacter and Salmonella in food and nanotechnology could lead to the next generation of these sensors (Patel 2002). For example, flexible, color-changing nano-based inserts are being developed to indicate detection of Salmonella, E. coli, and other pathogens. These inserts could be placed on milk cartons, inside ready-to-eat packaged salads, and on other food packaging to warn consumers that the product is no longer safe to eat.
- Nanosensor inserts in food packaging have been developed which could warn consumers that there has been a temperature violation and the product may be spoiled.
- In addition to detecting some food borne pathogens like Salmonella and E. coli under the Centers for Disease Control and Prevention's list of "Category B" agents, nanosensors can also be developed for food biosecurity to detect "Category A" agents like the pathogens that cause anthrax and botulism as well as other poisonous contaminants, such as heavy metals (e.g., arsenic, mercury and lead) and chemicals (e.g., dioxins, harmful pesticide residues, furans and polychlorinated biphenyls [PCBs]) (Tzeng and Branen 2005). Lee et al. (2009) have used nanotechnology to detect the DNA of SARS, Ebola and Anthrax.

Applications that Exist Mainly as Promising but Unproven Research Ideas

- Nanosized devices are under development that may help trace food or food ingredients to its source of origin (Chaudhry et al. 2008).
- Targeted delivery of salty taste using nanomaterials could potentially be developed and lead to reduced salt intake, in turn reducing hypertension and health disease (Chen, Weiss, and Shahidi 2006).

Source: Jean Buzby (2010)

To sum up, nanotechnologies have been applied to different categories: agriculture, food processing, food packaging and final products (i.e., supplements, nanodrops, nanosensors as indicators, etc.). Nanotechnology has begun to find potential applications in food and agriculture toward innovative functions very different from those that occur naturally. This opens up a new area of research and development.

Following a report by Nanoforum--a European Union sponsored thematic network-a food product is considered as ‘nanofoods’ when nanoparticles and nanotechnology techniques or tools are used during cultivation, production, processing or packaging of the food, not intending to produce atomically modified food or food produced by nanomachines and not by just throwing together a group of nanomaterials (Joseph and Morrison, 2006).

Moreover, commercialized or marketed ‘nanofoods’ can be found in the PEN inventory. A total of 105 items fall into this main category, with some products repeated in multiple categories. Specifically, it includes: 59 supplements (56.2%), such as micronutrient multivitamin complex produced with patented nanoparticulation technology and other minerals; 12 cooking applications (11.4%), for example, nanosilver teapots and kitchen- and table-ware; and 21 food storage products (20%), such as antibacterial silver nanoparticles integrated into food wraps or containers; and 5 nanofoods (4.8%).

In particular, these five nanofoods where nanotechnologies were applied directly into the content of final product of the foods are: a canola active oil released in 2004 in Israel that contains inhibit nanodrops to serve as a liquid carrier and compete with cholesterol for entering into the human blood system; a slim shake chocolate from a US company that is claimed to combine natural cocoa with new technique to create cocoa cluster-the Nanoceuticals and to enhance the taste and benefits without adding excess sugar; and three other food items such as maternal water from Argentina, Nanotea from China and Primea Ring in USA.

1.2. Is food nanotechnology bliss or curse?

New food technologies often enable a new era of development in agriculture and food system. Nanotechnology is of no exception. One of the major topics that researchers are interested in is the development and application of nanotechnology in food and agriculture (Kuzma and VerHage, 2006, Nord, 2009, Roco, 2008, Sozer and Kokini, 2009). Public perception and acceptance of these new technologies is another major research concern especially when it is food related (EuropeanCommission, 2004, Ronteltap, et al., 2011, Scheufele and Lewenstein, 2005, Siegrist, et al., 2007). The third major topic is the safety of nanotechnology applications to human health and the environment. Several international entities and governments have established risk assessment frameworks to estimate benefits and risks to human health and the environment through the use of nanotechnology in the food sectors (COT, 2007, EFSA, 2009, FDA, 2007, FSA, 2008). To date, these scientific studies have mixed results.

Since there is no general consensus regarding whether food nanotechnology is a bliss or curse, consumer preference for nanofoods is worth exploring as more products will be put into the production line and marketed in the near future. The purpose of this dissertation is threefold, first, to evaluate consumers' preference for food nanotechnology and other new food technologies (i.e., willingness-to-pay) with the use of a choice experiment (chapter 4). Second, to investigate social awareness and public acceptance of food nanotechnology (chapter 5). Third, to investigate the role of consumers' heterogeneities, including socio- economic and psychological factors, on the willingness-to-pay for each specific technology (chapter 5).

Chapter 2 Dissertation Motivations and Survey

2.1. Public Perception

2.1.1. Gap between nanotechnology and society

Nanotechnology and nanoscience have been promisingly transforming many aspects of agriculture and food production. Some are claiming it as the key to the next industrial revolution. Richard Smalley received the 1996 Nobel Prize in Chemistry for discovering one of the chemical structures at the center of the nanotechnology. In 1999, he spoke in front of a US congress subcommittee hearing:

> *"From stone, to copper, to bronze, iron, steel, and now silicon, the major technological ages of humankind have been defined by these atoms can do in huge aggregates, trillions upon trillions of atoms at a time, molded, shaped, and refined as macroscopic objects. Even … the smallest feature is a mountain compared to the size of a single atom. The resultant technology of our 20th century is fantastic, but it pales when compared to what will be possible when we learn to build things at the ultimate level of control, one atom at a time."*
>
> (Mathuna, 2009, Smalley, 1999)

Today, nanomaterials already appear in commercialized products as discussed in the previous chapter. The potential applications are only just beginning to be realized. Yet, much remains unknown about it. The following narratives that started with "Nanotechnology could …" have told both blessing and curses of this new technology in a broad view:

> *"… Nanotechnology could increase the speed of memory chips, and remove pollution particles in water and air and find cancer cells quicker. Nanotechnology could prove beyond our control, and spell the end of our very existence as human beings. … Nanotechnology could be the new asbestos. … Nanotechnology could alleviate world hunger, clean the environment, cure cancer, guarantee biblical life spans or concoct super-weapons of untold horror. … Nanotechnology could spur economic development through spin-offs of the research. Nanotechnology could harm the opportunities of the poor in developing countries. … Nanotechnology could become an instrument of terrorism. Nanotechnology could lead to the next industrial revolution. Nanotechnology could transform the food industry. … "*
> (Kelty, 2006)

Technology in general has made life safer and less burdensome throughout the span of human history when used for good objectives. However, limited knowledge of nanotechnology is a barrier bringing uncertainty and anxiety to the society. The very first PEN report was accomplished in 2005 with two national phone surveys (Cobb, 2005, Cobb and Macoubrie, 2004) of Americans' perceptions of nanotechnology. One of the major concerns addressed in the study was that even though huge benefits could be anticipated, the public hoped to be involved more and they had low trust in government. Additionally, another drawback was that a majority of respondents were scared of items produced through nanotechnology because they did not know what it was, and this would slow down development of the technology (Macoubrie, 2005).

Researchers in social and natural science are just beginning to understand the importance of developing a thorough study on public opinion pertaining to nanotechnology (Gaskell, et al., 2004, Roco, 2003, Scheufele and Lewenstein, 2005). As a result, one of the many challenges is whether building a systematic assessment of public attitudes toward and acceptance of nanotechnology is possible at this point, given the very early stage of the development of nanotechnology. Moreover, social scientists also have pointed out other challenges. For example, there is a limited amount of serious, published research into the ethical, legal, and social implications of nanotechnology (Mnyusiwalla, et al., 2003, Roco and Bainbridge, 2000). Ronteltap et al.(2011) reviewed most of existing literatures on the societal responses in the field of nanotechnology in general. The study concluded that there could be a pattern found for social science research in nanotechnology if following the studies of other technologies in an earlier age, e.g. biotechnology and nuclear technology. Meanwhile, as suggested in their study, risk perception would help build effective research framework for assessing nanotechnology.

Major benefits were, however, anticipated in the form of medical advances and improved consumer products according to results from the first PEN report. General technological progress was also seen as significant benefits, advances in environmental protection, reduced cost of energy, and improved food and nutrition and food safety (Macoubrie, 2005). In contrast, the report also found that the public strongly desired to be informed about the decision-making process of a new technology, especially if it was related to medicine and to food. My dissertation serves to fill the gap between social science and the natural science, especially in the consumers' point of view.

2.1.2. Policy and regulations

As consumers are exposed to benefits from using nanomaterials for enhancing products in food industry, they also need to be informed of risks and uncertainties. A recent debate highlights that the food industry has to use caution when including nano-sized particles as nutritional additives, flavorings, coloring or anti-bacterial coatings for packaging (Galland and Passoff, 2011). Anxiety relevant to food and food-related products comes from uncertainty or unawareness of the production processes and the potential negative effects on the human body. Nanofoods face such challenges.

Every day, many new consumer products are under development and may soon be on the market. However, the government, industry producers, and consumers may not be ready for these new products. Davies (2006) argues that even though there are a number of existing laws that provide some legal basis for reviewing and regulating nanoparticles, all of them suffer from major shortcomings of legal authority or lack of resources, or both. The situation is exacerbated as nanotechnology becomes increasingly complex in structure, function and applications. Current laws could provide only a weak basis to identify and protect the public from potential risks. Relevant discussions include the FDA (Schultz and Barclay, 2009, Taylor, 2006); EPA (Davies, 2007); RCRA (Resource Conservative and Recovery) (Breggin and Pendergrass, 2007); and others (Fiorino, 2010, Taylor, 2008), etc.

During the last decade, GM (genetically modified) foods made a big splash. European environmental organizations and public interest groups have been actively protesting against GM foods. GM crops have been modified to enhance desired traits such as increased resistance to pests and herbicides or improved nutritional content compared to conventional breeds. However, concerns have been swelling, including environmental hazards, human health risks, and economic concerns (Einsiedel, 2005). For example, there is no agreement about the potential harm to non-targeted organisms beyond the desired organism. Crops engineered for herbicide tolerance and weeds may cross-breed, resulting in the transfer of the herbicide resistance genes from crops to weeds to "superweeds" (Satterfield, et al., 2009).

The GM food debate not only failed to address environmental and health concerns, it overlooked the ownership and control issues. How society will be affected and who will benefit are also critical concerns. When it comes to nanotechnology, it is beneficial and necessary to bring out these concerns at an early stage. European environmental activists argued that nano-scale formulations of agricultural input products such as pesticide, fertilizers and soil treatments should be prohibited from environmental release until a new regulatory regime specifically designed to examine these products finds them safe (ETC, 2004). These fence-sitting arguments have already jeopardized the potentials of the development of nanotechnology. Therefore, it may again be necessary to invite the public into the decision-making process even before products are commercialized. Meanwhile, comparison between genetically modification technology and nanotechnology may ease public's understanding of both.

2.1.3. Previous Studies on Consumer acceptance and Willingness-to-Pay

The literature regarding consumer acceptance and willingness-to-pay (WTP, hereinafter) for nanofoods is quite limited. Siegrist, et al. (2007) conducted a survey on consumer acceptance and WTP for four different food products that were or might be produced utilizing nanotechnology in the German-speaking part of Switzerland. Results showed that nanotechnology packaging is perceived as being more beneficial than nanofoods, and that social trust in the food industry is an important factor directly influencing new productions.

Roosen, et al. (2011) conducted a choice experiment in Munich, Germany in 2009. Their questionnaire focused on WTP for a hypothetical product--a one-liter bottle of orange juice enriched with Vitamin D through nanotechnology. They defined nanoproducts as the technique applied to food, namely food fortifications. Their findings indicate that the value of information for consumers was affected by its access conditions and its contents. The results are of particular importance in a market where different types of uncertain scientific knowledge and information are available. Results also suggested that health information decreased WTP, while social and environmental information only slightly decreased the WTP.

Although there are a large number of industrial, household, and food items being produced with nanotechnology in the US, no study has assessed the US consumers' attitudes and WTP. The present dissertation is an effort to fill this void. In addition, the application of choice model and WTP estimates enables not only qualitative but also quantitative analysis of consumer preference, which is the major contribution of this dissertation. This is the very first study to include both qualitative and quantitative aspects of the issues involved.

2.2. Objectives and Outlines of this dissertation

2.2.1. Objectives and Expected Contributions

The aforementioned scientific and public debate regarding nanotechnology and especially those applied in foods generated our interests in societal response to nanotechnology. Important questions for consumers, industry and policy makers have been raised (Buzby, 2010): Is nanotechnology for food application safe for human health? What are the potential environmental impacts? What are the key marketing concerns?In respect to public understanding and acceptance, this study concentrates on social science and consumer behavior. In a nutshell, this project is designed to cover the following objectives:

OBJECTIVE 1: to investigate public awareness, general attitude about nanotechnology, and confidence in the benefit of this revolution, especially in comparison with other new technologies;

OBJECTIVE 2: to analyze consumers' risk and benefit perception about new food technologies;

OBJECTIVE 3: to estimate consumers' willingness-to-pay for novel food attributes and tradeoffs for potential environmental benefits and threats, and associated sustainability consciousness of the public;

OBJECTIVE 4: to examine heterogeneities across individuals, and determine factors impacting consumers' perception and acceptance of nanotechnology and other new technologies as applied to food.

This study contributes to the literature with a more detailed analysis of societal response to and public acceptance of nanotechnology. Throughout the results from this study, empirical evidence for decision-making for both marketers and policy makers will be provided. The examinations of US consumers' preferences and WTP for nanofoods are the main contribution of this dissertation as it is the very first study of such application.

2.2.2. Dissertation Outline

The rest of the dissertation is structured as follows: the survey design and summary statistics in this chapter. Chapter 3 introduces economic and econometric theoretical foundation. Chapter 4 provides an empirical analysis of consumer preference of nano-attributes and other attributes. Chapter 5 examines the impact of demographic characteristics and consumers' perception statics on consumer preference of new food technologies as a means to to explain heterogeneities across individuals. Lastly, chapter 6 presents the conclusions and suggests future directions.

2.3. Survey

2.3.1. Survey Designs

For the purpose of this project, we conducted an online US nationwide survey at the end of November in 2012 (9:00 am November 29th, 2012 - 3:00 pm December 1st, 2012) through SurveyMonkey, Ltd., a professional survey company. The survey company has a panel of up to 3 million registered respondents. Of those who were contacted, 1,319 started the survey. It yielded a total of 1,131 usable responses, while ruling out incomplete surveys because of self-quitting or being cut out when the targeted 1,000 responses were reached. The survey was sent out simultaneously in twelve different versions. Summary statistics are provided in Table 2.1. However, in this dissertation we focus on the use of choice cards, which divided the survey into two different versions.

Table 2.1 Survey Response Number Summary

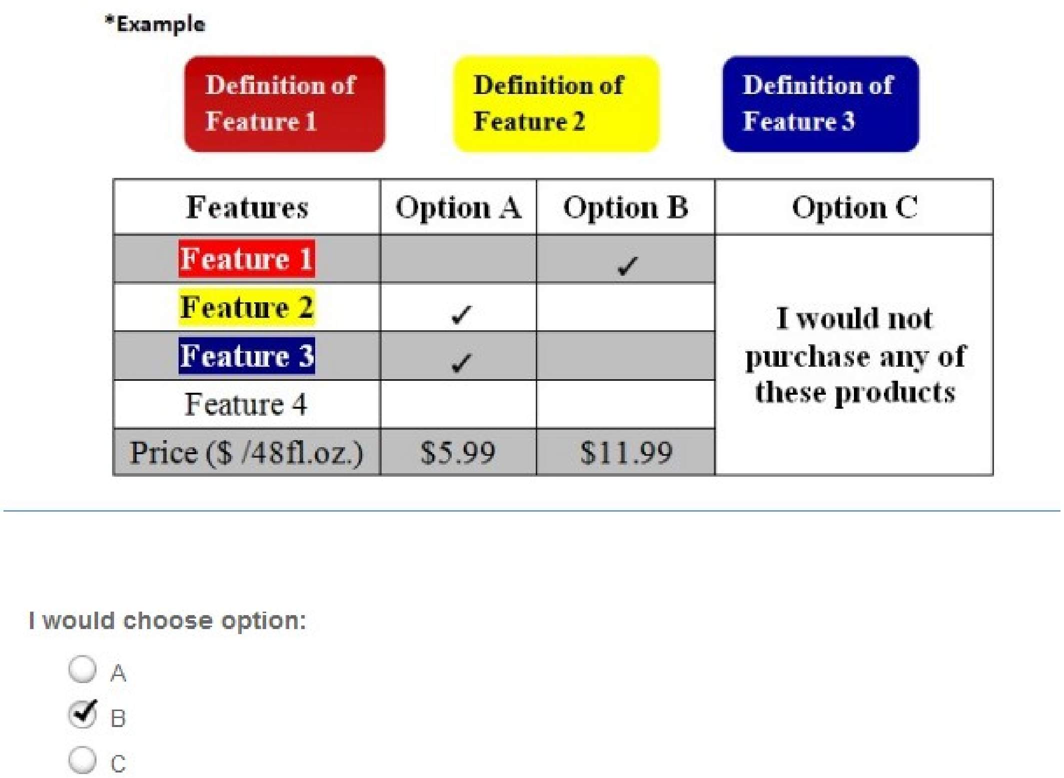
Survey Version	Informational Report Version	Choice Card Version	Total Started	Total Finished	%	If more than 5 minutes	%	If more than 10 minutes	%
1	1	1	110	96	87.3%	82	74.5%	56	50.9%
2	1	2	110	98	89.1%	80	72.7%	58	52.7%
3	2	1	110	97	88.2%	71	64.5%	46	41.8%
4	2	2	110	93	84.5%	74	67.3%	55	50.0%
5	3	1	149	135	90.6%	107	71.8%	75	50.3%
6	3	2	110	96	87.3%	78	70.9%	59	53.6%
7	4	1	110	90	81.8%	72	65.5%	50	45.5%
8	4	2	110	89	80.9%	72	65.5%	54	49.1%
9	5	1	100	79	79.0%	62	62.0%	42	42.0%
10	5	2	100	86	86.0%	72	72.0%	45	45.0%
11	6	1	100	86	86.0%	71	71.0%	54	54.0%
12	6	2	100	86	86.0%	73	73.0%	53	53.0%
		Total	**1319**	**1131**					

In the questionnaire, canola oil was chosen as the target product. The first part of the survey asked about consumers' buying habits regarding canola oil in general. It then extended to asking about consumers' awareness as well as acceptance of canola oil products when different nanotechnologies were used. The last part of the questionnaire veered back to assess consumers' attitudes towards general nanotechnology applications. In summary, the six parts of the questionnaire are as follows:

- **Part I** examines respondents purchasing habits for conventional, marketed canola oil, to provide information for comparison and reference to hypothetical products in later parts of the survey. It also serves to attract respondents' interest to read and respond to the rest of the survey (Dillman, 2000);
- **Part II** brings respondents into a new realm of food science, and collects their intuitive perceptions on a variety of technologies applied to food and food related products;
- **Part III** consists of choice experiments intended to elicit consumer WTP for nano-attributes, which will be explained in detail later in this chapter;
- **Part IV** examines public trust in new technology and the oversight system;
- **Part V** raises questions adapted from related literature about five aspects of nanotechnology: ethical, social, economic, environmental, and human health issues;
- **Part VI** collects respondents' demographic information.

2.3.2. Choice Experiment

This section describes choice experiment design. We set up experimental scenarios for respondents in Part III of the questionnaire. Instructional and informational reports are given before choice scenarios. Figure 2.1 presents an example. Six informational reports provide different levels of information about nanotechnology. They are included after an instructional page. Most importantly, definitions of nano-attributes are given twice: in a separate page with a full description of the attributes before each choice scenario; and in colored cards with abstract descriptions above the choice scenario. Both definitions parts are shown in figure 2.2.



*Example

Definition of Feature 1 | Definition of Feature 2 | Definition of Feature 3

Features	Option A	Option B	Option C
Feature 1		✓	I would not purchase any of these products
Feature 2	✓		
Feature 3	✓		
Feature 4			
Price ($ /48fl.oz.)	$5.99	$11.99	

I would choose option:

- A
- B ✓
- C

Figure 2.1 Choice Scenario Example

I. Full Descriptions

Three types of nanotechnology may be relevant to canola oil production:
(A) Canola seeds might be produced under nanomonitoring in that water, fertilizer, or pesticide may be applied more efficiently and therefore reduces production cost and impr ove environmental quality. We refer to this technology as **<u>NanoAgriculture</u>**.

(B) Canola oil bottle may be produced through nanotechnology to keep canola oil fresh for a longer period of time and to alert consumers if the quality of oil starts to deteriorate. We refer to this technology as **<u>NanoPackaging</u>**.

(C) Nanodrops may be added to canola oil to block cholesterol from being absorbed by human digestive system. We refer to this technology as **<u>NanoDrop</u>**.

II. Abstract Description Cards

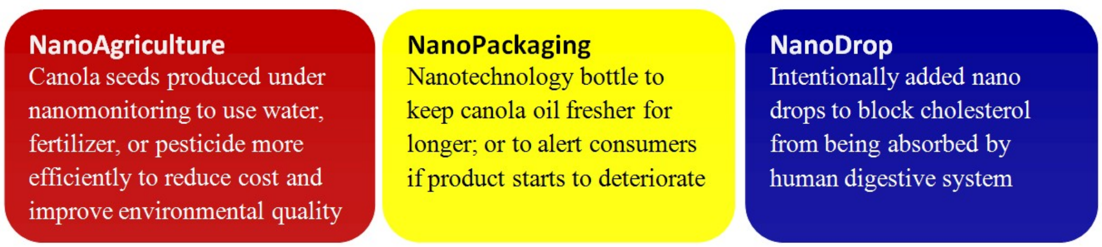


Figure 2.2 Definition parts

Each choice scenario consists of three alternatives (two canola oil options and one would-not-buy option). Each whole choice profile contains five categories: three nano-attributes (NanoAgriculture, NanoPackaging and Nanodrop), a GM attribute and the price. Table 2.2 gives detailed descriptions for the levels of these attributes and corresponding variables. The two canola oil alternatives were constructed from fractional factorial orthogonal design, instead of full factorial design which is costly in terms of respondents' fatigues. The design was generated in software SAS 9.3. It yielded 16 possible combinations of levels (or choice sets) and were blocked into 2 versions of the questionnaire, which were referred to as the 2 versions of choice card introduced in Table 2.1. Each version consists of eight choice scenarios. Four price levels were used in the choice experiment: \$2.99, \$5.99, \$8.99 and \$11.99 according to market research in major grocery stores. Other non-price attributes are all binary options (YES or NO). One of the full questionnaires is attached in the appendix.

Table 2.2 Attributes Levels and Descriptions

Attributes	Levels	Variables	Descriptions
Price ($/per 48 fl.oz.)	$2.99 $5.99 $8.99 $11.99	PRICE	Refers to canola oil price in retail grocery store where the respondents typically shops
Nano-attributes			
Nanopackaging	YES NO	NANOPACK	Refers to elaborate nano-attributes provided in figure 2.2
NanoAgriculture	YES NO	NANOAG	
NanoDrops	YES NO	NANODROPS	
Non-GMO	YES NO	NonGMO	Means the canola oil was produced without GMO involved

2.3.3. Demographic Characteristics

In the sample, seventy percent of the respondents reported they did purchase canola oil in the past year (see Figure 2.3). The mean age of the respondents is 40.76 years old and the mean household size is between 2 to 3 persons (mean=2.66) and average household annual income is $65,160. The results also include other demographics, such as marriage status, gender and community. As presented in the Table 2.3, 56% of the respondents were male, slightly more than the US average. A total of 45.78% of the sampled consumers were married. A third of the respondents lived in city, while 42.68% lived in suburb area and the rest 24% lived in small town or rural areas. Additionally, over a half of the respondents were employed either full-time or part-time. The education achievement distribution revealed the sample as higher educated respondents, compared to the US population. About 24.58% of the respondents obtained some college degree, higher than the US Census results (19.46%). Furthermore, about 17.6% of the respondents had advanced education, with a post graduate degree, e.g. master or PhD, or other professional degree. Overall, this sample corresponded closely to the US population in household size, household annual income, and gender distribution, but it slightly over represented male, older respondents and education attainment, as shown in Table 2.3.

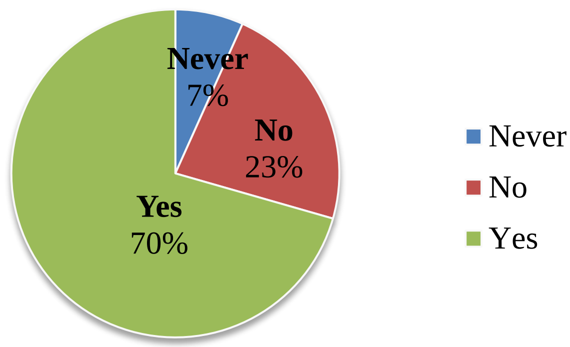


Figure 2.3 Did your household ever purchase canola oil in the past year?

Table 2.3 Sample Demographic

Variable	Group	Percent	Sample Mean	US Census
Household size			2.66	2.55[a]
Age			40.76	37.2[b]
Education	Never Attend School	0.27%		0.36%
	Less than 9th grade	0.09%		4.24%
	9th to 12th grade, no diploma	1.77%		8.58%
	High School graduate	15.74%		30.01%
	Post secondary trade or technical school certificate/Degree	5.84%		4.00%
	Some college, no degree	24.58%	15	19.46%
	College Diploma/Degree	20.42%		23.59%
	University undergraduate degree	7.25%		
	Some Post Graduate University	5.57%		
	Post Graduate Degree(e.g. master or PhD, or other professional degrees)	17.60%		9.76%
	Decline to Response	0.88%		
Male	Male	56.03%		0.49[b]
	Female	43.97%		
Marriage Status	Married	45.78%	0.46	
	Others	54.22%		
Household Income				51.42 k[b]
	Less than $20000	14.68%		
	$20000~$29999	11.05%		
	$30000~$39999	11.76%		
	$40000~$49999	10.43%		
	$50000~$59999	8.93%		
	$60000~$69999	7.34%	65.16 k	
	$70000~$79999	7.34%		
	$80000~$89999	4.69%		
	$90000~$99999	5.22%		
	$100000~$200000	15.03%		
	More than $200000	3.54%		
Community	City	32.80%		
	Suburb	42.68%		
	Small Town	13.62%		
	Countryside or Rural Area	10.96%		

[a] US Census
[b] Current Population Survey 2012 Annual Social and Economic Supplement, formerly called the March Supplement, http://www.census.gov/hhes/www/cpstables/032012/hhinc/hinc01_000.htm

Chapter 3 Theoretical Foundation

3.1. Economic Theory Foundation

3.1.1. Lancaster Demand Theory

Lancaster's theory of demand

Lancaster extended the conventional utility framework and built the "new theory of consumer demand" (1966). The seminal premise of this framework is that consumers are not seeking to acquire goods themselves but the characteristics. Rather, product demand is affected by various characteristics or attributes the product possesses. Alternatively, utility is derived not from a good itself, tb from attributes that are intrinsic to the good.

Darby and Karni's theory of product attributes

Darby and Karni (1973) expended Lancaster's work in that intrinsic characteristics of a good can be categorized into search, credence and experience attributes. Search attributes can be ascertained prior to purchase. Experience attributes cannot be determined prior to purchase, but can be detected during consumption. Whereas, credence attributes cannot be examined even after consumption.

3.2. Econometric Theoretical Framework

After knowing the choice experiment design in Chapter 2 and Lancaster's theory of demand for quality, it is natural to infer the decision-making process that the respondent will go through during the survey. Suppose individual i faces a choice (herein, he/she will choose a hypothetical canola oil item) among alternatives consisting of different attributes, and chooses j (where, j=1, 2, 3... J) among all alternatives in the t-th choice situation. The characteristics of the product are represented by x_{ijt} (x= BUYNO, NanoAgriculture, NanoDrop, NanoPackaging, NonGM, PRICE). It is assumed that the consumer will choose alternative j, preferring it to other options, if and only if the associated utility of j is greater than or at least equal to that of any other alternatives, *ceteris paribus*. Mathematically, the utility can be represented in a Random Utility Model (McFadden, 1974):

$$U_{ijt} = \boldsymbol{X}_{ijt}\boldsymbol{\beta} + \varepsilon_{ijt}$$

where U_{ijt} refers to indirect utility obtained by individual i, which is a linear function of observable vector of attributes $\boldsymbol{X}_{ijt}$ and its coefficient vector $\boldsymbol{\beta}$, to be estimated; ε_{ijt} represents the random error which captures all other unobservable factors that influence the choice process. McFadden showed that if the error terms follow an independent and identical distributed (iid) maximum extreme value Type I distribution, the utility maximization process leads to the choice probability of alternative j chosen in choice set t:

$$P_{ijt} = \frac{exp(\boldsymbol{X}_{ijt}\boldsymbol{\beta})}{\sum_{k=1}^{J} exp(\boldsymbol{X}_{ikt}\boldsymbol{\beta})}$$

This is the form of conditional logit model. However it suffers from two major limitations: 1) can not represent random taste variation, 2) does not avoid the restrictive substitution pattern suggested by the Independent of Irrelevant Alternatives (IIA) property (Train, 2003). Mixed logit models address these limitations. Recent improvement in computational packages promoted empirical applications of the mixed logit model, and this dissertation used STATA 12.

Following Train (2003), parameters in vector $\boldsymbol{\beta}$ are assumed to be random variables and may vary across individuals in the sample, rather than fixed coefficients as in the conditional logit model. Suppose the distribution of $\boldsymbol{\beta}$ is specified as $\boldsymbol{\beta} \sim \mathbf{H}(\boldsymbol{\theta}, \Delta)$. $\mathbf{H}$ can be the individual probability distribution function and parameters $\boldsymbol{\theta}$ and Δ are the mean and variance. The benefit from the mixed distribution is that unobserved variation can be represented in the form of any appropriate distribution by specifying the form of function H. Amongr the commonly used distributions are normal, lognormal and uniform. Given the random parameter context, the choice probability is updated as:

$$P_{ijt} = \int \frac{exp(\boldsymbol{X}_{ijt}\boldsymbol{\beta})}{\sum_{k=1}^{J} exp(\boldsymbol{X}_{ikt}\boldsymbol{\beta})} h(\boldsymbol{\beta}) d\boldsymbol{\beta}$$

$h(\boldsymbol{\beta})$ is the (joint) density function of H for parameters $\boldsymbol{\beta}$**.** The integral is approximated by simulation. Consequently, instead of $\boldsymbol{\beta}$, parameters $\boldsymbol{\theta}$ and Δ are to be estimated.

In addition to product attribute variables in a basic mixed logit model, other factors may also affect the decision process. A natural extension of the model would be to consider respondents' individual characteristics, including their perceptions and attitudes. Detailed demographic information and perception and attitude results for this sample file will be introduced in the next section.

Our specification of the mixed logit model with interactions yields:

$$U_{ijt} = V_{ijt}\left(\boldsymbol{X}_{ijt}, \boldsymbol{D}, \boldsymbol{P}; \boldsymbol{\beta}, \boldsymbol{\gamma}\right) + \varepsilon_{ijt}$$

$$V_{ijt} = \boldsymbol{X}_{ijt}\boldsymbol{\beta} + \boldsymbol{\gamma}^{\boldsymbol{D}}\left(\boldsymbol{X}_{ijt} * \boldsymbol{D}_i\right) + \boldsymbol{\gamma}^{\boldsymbol{P}}(\boldsymbol{X}_{ijt} * \boldsymbol{P}_i) + \varepsilon_{ijt}$$

$$\boldsymbol{X}_{jt} = [\text{BUYNO}, \text{NanoAgriculture}, \text{NanoDrop}, \text{NanoPackaging}, \text{NonGM}, \text{PRICE}]_{jt}$$

$$\boldsymbol{D}_i = Demographics$$

$$\boldsymbol{P}_i = Perceptions/Attitudes$$

And, the choice probability function is:

$$P_{ijt} = \int \frac{exp\left(\boldsymbol{X}_{ijt}\boldsymbol{\beta} + \boldsymbol{\gamma}^{\boldsymbol{D}}\left(\boldsymbol{X}_{\boldsymbol{ijt}} * \boldsymbol{D}_{\boldsymbol{i}}\right) + \boldsymbol{\gamma}^{\boldsymbol{p}}(\boldsymbol{X}_{\boldsymbol{ijt}} * \boldsymbol{P}_{\boldsymbol{i}})\right)}{\sum_{k=1}^{J} exp\left(\boldsymbol{X}_{ikt}\boldsymbol{\beta} + \boldsymbol{\gamma}^{\boldsymbol{D}}\left(\boldsymbol{X}_{\boldsymbol{ijt}} * \boldsymbol{D}_{\boldsymbol{i}}\right) + \boldsymbol{\gamma}^{\boldsymbol{p}}(\boldsymbol{X}_{\boldsymbol{ijt}} * \boldsymbol{P}_{\boldsymbol{i}})\right)} h(\boldsymbol{\beta}) d\boldsymbol{\beta}$$

$$\boldsymbol{\beta} \sim Normal(\boldsymbol{\theta}, \Omega)$$

The marginal value or the WTP for an attributes is given by the ratio of the attribute coefficient to the price coefficient which is set to be fixed as above, such that:

$$Marginal\ Value = -\frac{\beta_{\boldsymbol{X}} + \gamma_X^D * D + \gamma_X^P * P}{\beta_{PRICE} + \gamma_{PRICE}^D * D + \gamma_{PRICE}^P * P}$$

Both basic mixed logit and mixed logit with interactions make it possible to account for heterogeneity in preference of attributes, except for price to avoid unrealistic welfare measurers associated with a random price parameter (Meijer and Rouwendal, 2006). An alternative approach is to report the distribution of the WTP as the distribution of the attributes or interactions coefficient scaled by the fixed price coefficient, rather than a single representative WTP when specifying demographics and other factors at the sample average levels.

Model fitness is revealed by both the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), which are two popular measures for comparing maximum likelihood models. The information criteria are calculated as:

$$AIC = -2 * ln\, L + 2 * k$$

$$BIC = -2 * lnL + ln(N) * k$$

where,

$$k = number\ of\ parameters\ estimated$$

$$N = number\ of\ observations$$

AIC and BIC can be viewed as measures that combine fit and complexity. Fit is measured negatively by $-2 * ln\, L$; the larger the value, the worse the fit. Complexity is measured positively, either by $2 * k$(AIC) or $ln(N) * k$(BIC). Given two models fitted on the same data, the model with the smaller value for the information criterion is considered to be better (Akaike, 1974, Raftery, 1995).

Another important good of fitness criterion is McFadden R^2 (McFadden, 1974), known as "likelihood ratio index", comparing a model without any predictor to a model including all predictors. The formula is expressed as:

$$McFadden\ R^2 = 1 - \frac{ln\boldsymbol{\hat{L}_{full}}}{ln\boldsymbol{\hat{L}_{intercept}}}$$

$\boldsymbol{\hat{L}_{full}}$=estimated likelihood of model with predictors

$\boldsymbol{\hat{L}_{intercept}}$= estimated likelihood of model without predictors

A likelihood falls between 0 and 1, so the log of a likelihood is less than or equal to zero. If a model has a very low likelihood, then the log of the likelihood has a larger magnitude than the log likelihood of a more likely model. Thus a small log likelihood ratio indicates that the full model is better than the intercept model. The McFadden R^2 is larger in this case.

However, the McFadden R^2 will increase if the number of regressors increased, such that the adjusted McFadden R^2 is used to avoide such issues. The adjusted McFadden R^2 mirrors the adjusted R^2 in OLS by penalizing a model for including too many predictors (Verbeek, 2004). The adjusted McFadden R^2 is:

$$Adjusted\ McFadden\ R^2 = 1 - \frac{ln\boldsymbol{\hat{L}_{full}} - K}{ln\boldsymbol{\hat{L}_{intercept}}}.$$

Chapter 4 Public Acceptance of and Willingness to Pay for Nanofood: Case of Canola Oil

4.1. Introduction

Science in agricultural development has brought real benefits to farmers, processors and consumers through the development and implementation of new knowledge and technology over the past decades. New food technologies enable a new era of agriculture and food systems by bringing innovative applications, improving agricultural productivities. So far, nanotechnology has been no exception. In food science, nanotechnology seems to provide a sound framework to understand the interactions and assembly behavior of food components (Sangunsri and Augustin, 2006) in microscopic scale, which may influence food structure, rheology and properties in counterpart bulk form.

Nanotechnology has already begun to attract the attention of investors, media and policy makers recently. Progress among researchers continues to develop and assess this new technology. Meanwhile, the public demands to be informed and involved in decision making about the technology (Macoubrie, 2005), especially when billions of tax dollars are invested in nanotech research and development. Therefore, it is crucial for policy makers and other stakeholders to have a good grasp of public opinion in the early stage of nanotechnology development.

Previous studies have examined public understanding and perception of general nanotechnology via surveys in the US, Canada, or both (Cobb and Macoubrie, 2004, Currall, et al., 2006, Einsiedel, 2005, Hart, 2009, Macoubrie, 2005, Priest, 2006, Smith, et al., 2008). Their results suggested that consumers' knowledge about nanotechnology is generally limited, and even more so for food nanotechnology. Yet, their initial reaction to this technology is generally positive, which may motivate more applications and final products' commercialization in the future. Hence, qualitative and quantitative research about this new technology is necessary for future market success.

A survey conducted in Switzerland found that nanotechnology food packaging was assessed as less problematic than nanotechnology food (Siegrist, et al., 2007). Another recent survey carried out in Germany (Roosen and Bieberstein, 2011) evaluated participants' willingness to pay (WTP) for food produced using nanotechnology. Results implied that health information offered to consumers while they were making a purchase was a priority and significantly decreased WTP. However societal and environmental information did not significantly influence WTP.

Although these results to some extent shown consumers' recognitions to nanotechnology, little has been done to assess consumers' acceptance of different nanotechnology applications of food, especially in the US. The objective of our study and survey is to empirically estimate consumers' acceptance of nanotechnology techniques, particularly when applied to food products in different sectors: production, packaging and final products. To our knowledge, the results from our study provide a key contribution as the first choice-based conjoint analysis of consumer preference and the first systematic survey for food related nanotechnology.

4.2. Background

Scientists and industry have already used nanotechnology to bring advances into many segments of the food industry, from ***agriculture*** (e.g. precision farming and nanosensors to monitor production; smart delivery systems; water development; etc.), to **f*ood processing*** (e.g. encapsulation technique for better flavor and odor; food texture or quality improvement; etc.), to ***food packaging*** (e.g. UV-protection; stronger, more impermeable polymer film; smart food wrapper), and to ***nutrition supplements*** (e.g. nutraceuticals with vitamin enhancement; natural molecular clusters in food item; etc.) (Duncan, 2011, ETC, 2004, HelmutKaiserConsultancy, 2006, Hillie, et al., 2006, Joseph and Morrison, 2006, Kuzma and VerHage, 2006, Miller and Senjen, 2008). Generally, nanotechnology is employed for many current and potential food applications.

The Project on Emerging Nanotechnologies (PEN), which is sponsored by both the Woodrow Wilson International Center for Scholars and the Pew Charitable Trust, compiles and publishes an online inventory of nanotechnology-based consumer products currently marketed worldwide on an ongoing basis. This searchable PEN inventory is not comprehensive, and listed items are those claimed by manufacturers rather than certified by an independent third party as an actual use of nanotechnology. Nevertheless, it is believed to be the most accurate account of commercialized nanotechnology applications. For the purpose of this study, we examine and summarize only consumer products in the category of food and agriculture. A total of 105 food or food related products were listed under this category through March 2011, the most recent release date. Four subcategories are included: cooking supplies, food, storage and supplements. However, agricultural products are not obvious in this inventory.

Duncan (2011) suggested another classification by dividing these consumer products into four groups: agriculture, food processing, food-related products and nutrition products. In line with above research, we assembled all different techniques applied in agriculture and food in this study, but into three groups: ***NanoAgriculture***, ***NanoPackaging***, ***Nanodrops***. We use canola oil as the carrier product throughout the survey. The three types of nanotechnology may be relevant to canola oil production as follows: (A) Canola seeds might be produced under nanomonitoring in that water, fertilizer, or pesticide may be applied more efficiently and therefore reduces production cost and improve environmental quality. We refer to this technology as ***NanoAgriculture***. (B) Canola oil bottle may be produced through nanotechnology to keep canola oil fresh for a longer period of time and to alert consumers if the quality of oil starts to deteriorate. We refer to this technology as ***NanoPackaging***. (C) Nanodrops may be added to canola oil to block cholesterol from being absorbed by human digestive system. We refer to this technology as ***NanoDrops***. We refer to the three attributes as nano-attributes hereafter and all of these are indicator variables that are valued at one if the corresponding attribute is present, and zero otherwise.

4.3. Survey Description

We conducted a nationwide online survey that targeted typical US consumers. The choice experiment (CE) embedded in the survey enables elicitation of WTP associated with different nanotechnologies pertaining to agriculture and food. The CE attributes were adopted from previous literature and from PEN inventories as discussed previously.
The survey contained six sections. The first two sections contain basic questions on consumption habits for general canola oil and beliefs about food technology applied to food items, which were designed to attract consumers' attestations in the beginning of the survey (Dillman, 2000). The third section contains the choice experiment, where each respondent was shown eight choice sets out of a total of sixteen. The last two sections include questions about consumer perception and attitude toward nanotechnology in general and some demographic information. The sample screened only adult consumers. Descriptive statistics are provided in Table 2.3. Demographics compare closely to the US Census, which indicates the sample is reasonably representative.

In the choice experiment, besides nano-attributes mentioned previously, NONGMO was also included as an attribute indicating the food item is produced and/or packed, delivered and avoids being contaminated by any genetically modified organisms. This attribute was a dummy variable as well. Lastly, four price levels were used according to market research of typical canola oil: $2.99, $5.99, $8.99 and $11.99. These levels allow us to empirically compare the utility associated with each of the attributes. From these, implications could be drawn about which were attributes were most accepted and valued by consumers. All levels and attributes were introduced in Table 4.1. Recall, they are the same as in Table 2.2 in chapter 2. In order to reduce respondents' burden, the fractional factorial design was adopted. It yielded sixteen choice profiles with two canola oil alternatives and a buyno (Would-not-buy) option. More details about the choice experiment and survey design are provided in chapter 2.

Table 4.1 Attribute Levels and Descriptions

Attributes	Levels	Variables	Descriptions
Price ($/per 48 fl.oz.)	$2.99 $5.99 $8.99 $11.99	PRICE	Refers to canola oil price in retail grocery store where the respondents typically shops
Nano-attributes			
Nanopackaging	YES NO	NANOPACK	Refers to nano-attributes definitions
NanoAgriculture	YES NO	NANOAG	
NanoDrops	YES NO	NANODROPS	
Non-GMO	YES NO	NONGMO	Means the canola oil was produced without GMO contaminated
Would-not-buy	YES NO	BUYNO	Alternative option

4.4. Model and Specification

Logit models have been widely used to estimate choice experiment data, including both conditional logit (CL) and mixed logit model (ML) (Erdem and Rigby, 2011, Hu, et al., 2005, Lim, et al., 2012, Lusk and Sullivan, 2002, Roosen, et al., 2011, Teratanvat and Hooker, 2006). The models follow the (RUM) Random Utility Model framework (McFadden, 1974), such that utility U_{ijt} associated with respondent i for alternative j in choice set t is a linear function of observable vector of attributes $\boldsymbol{X}_{ijt}$ with remaining unobservable component represented by ε_{ijt}, as followed:

$$U_{ijt} = V(\boldsymbol{X}_{ijt}\boldsymbol{\beta}) + \varepsilon_{ijt}$$

The solution will be defined through maximization: individual I will choose choice j if and only if he/she obtains higher satisfaction by this choice among all other alternatives, or mathematically, $U_{ij} > U_{im}\ for\ all\ m \neq j$. Therefore, this model provides a set of parameter weights on the attributes that maximizes the likelihood of realizing the observed choice, and the choice probability of alternative j chosen in choice set t by individual i is given as:

$$\pi_{ijt} = \frac{exp\left(\boldsymbol{X}_{ijt}\boldsymbol{\beta}\right)}{\sum_{k=1}^{J} exp(\boldsymbol{X}_{ikt}\boldsymbol{\beta})}$$

The mixed logit model assumes that coefficients in vector $\boldsymbol{\beta}$ are random parameters, allowing variations across individuals. Then the mixed choice probability becomes (Greene, 2000, Train, 2003):

$$\pi_{ijt} = \int \frac{exp\left(\boldsymbol{x_{ijt}\beta}\right)}{\sum_{k=1}^{J} exp(\boldsymbol{X}_{ikt}\boldsymbol{\beta})} h(\boldsymbol{\beta}) d\boldsymbol{\beta}$$

, where $h(\boldsymbol{\beta})$ is the mixing distribution, which is specified as normal in this study.

In both CL and ML, the observable component can be expressed according to our specification in this study:

$$V_{ijt} = \alpha * \text{price}_{\text{ijt}} + \boldsymbol{X}_{ijt}\boldsymbol{\beta}$$

$$\boldsymbol{x}_{ijt} = [BUYNO, NANOAG, NANOPACK, NANODROPS, NonGMO]_{ijt}$$

The price level variable $price_{jt}$ along with its parameter α, which is specified as fixed to avoid an unrealistic positive coefficient associate with price and to ease the WTP calculations (Meijer and Rouwendal, 2006, Olsen, 2009). Consistently, the choice probability is now:

$$\boldsymbol{CL}: \pi_{ijt} = \int \frac{exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta}\right)}{\sum_{k=1}^{J} exp\left(\alpha * \text{p}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta}\right))} d\boldsymbol{\beta}$$

$$\boldsymbol{ML}: \pi_{ijt} = \int \frac{exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta}\right)}{\sum_{k=1}^{J} exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta}\right)} h(\boldsymbol{\beta}) d\boldsymbol{\beta}, \text{where } \boldsymbol{\beta} \sim Normal(\boldsymbol{\theta}, \Omega)$$

The marginal value or WTP for an attributes is given by the ratio of the attribute coefficient to the price coefficient which is set to be fixed as above, such that:

$$\text{WTP}_{\text{j}} = -\frac{\beta_j}{\alpha}$$

$$\text{j} = [\text{BUYNO, NANOAG, NANOPACK, NANODROPS, NONGMO}]$$

The calculation of WTP contains fixed coefficient α and random coefficients $\boldsymbol{\beta}$. In ML estimation, results report ***distributions*** for not only mean but also standard error for $\boldsymbol{\beta}$. Based on the model result, the standard errors of WTP measures incorporate both mean and standard deviation results, which provides a better description of WTP distribution. An alternative approach is to report distribution of the WTP as the distribution of the attributes or interactions coefficient scaled by the fixed price coefficient, rather than a single representative WTP when holding demographics and other factors at the sample average levels (Hole and Kolstad, 2012).

4.5. Estimate Results

The results of CL and ML models are provided in Table 4.2 and Table 4.3. The log-likelihood scores attest to how well the model explained the variation in the data. As a result, the ML model is more efficient than CL model (Log Likelihood= -9415.447 in CL and -7785.278 in ML). Four ($\sigma_{BUYNO}, \sigma_{NonGMO}, \sigma_{NANOAG}, \sigma_{NANODROPS}$) out of five of the standard deviations of the random coefficients are strongly statistically significant at the 1% level, which suggests stronger explanatory power for the ML model compared to the CL model. Other model fitness criteria are also given in both tables: Pseudo/Adjusted McFadden R^2, AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion). As depicted, Pseudo R^2 is higher in the ML model suggesting higher explanatory power; both AIC and BIC are smaller in ML model indicating better fit to the data.

In the CL model, all coefficients are statistically significant at least at the 5% significance level, except for the coefficient for variable NANOPACK. The interpretation is straightforward: if not choosing any of the canola oil (where BUYNO=1) consumers' utility is reduced; a negative association is observed between price and canola oil products; consumers strongly preferred product without GM ingredients or GM contaminated as the coefficient for NONGMO is strongly positive; coefficients for Nano-attributes were different from each other. The coefficient for NANOAG is significant and negative, indicating that consumer did not prefer canola oil produced with nanotechnology. NANOPACK is not significantly different from zero, indicating that consumers valued the canola oil relatively the same, either with or without nanotechnology package. However, a significantly positive relationship was observed between consumers' utility and the NANODROPS attribute, implying the functional benefits underlying this attribute drew attention from consumers and they valued it positively. WTP estimates based on the CL model are also provided in the last column in the Table.

Table 4.2 Conditional Logit Model Results

Variables	Coeff		Std. Err.	P Value	[95% Conf. Interval]		WTP
BUYNO	-0.9090	***	0.0477	0.00	-1.0025	-0.8156	-$7.33
PRICE	-0.1241	***	0.0046	0.00	-0.1330	-0.1152	--
NonGMO	0.1318	***	0.0326	0.00	0.0680	0.1957	$1.06
NANOAG	-0.0644	**	0.0292	0.03	-0.1215	-0.0072	-$0.52
NANOPACK	-0.0174		0.0298	0.56	-0.0758	0.0411	(-$0.14)
NANODROPS	0.0646	**	0.0271	0.02	0.0114	0.1178	$0.52
Log Likelihood	-9415.447						
Adjusted Pseudo R^2	0.0421						
AIC	18842.890						
BIC	18892.080						

and * represent 5% and 1% significance level respectively.

Next, a mixed logit model was estimated with random coefficients for BUYNO, NONGMO, and three Nano-attributes (NANOAG, NANOPACK, NANODROPS) following normal distributions and the coefficient for price being fixed, shown in Table 4.3. Recall, the fit of the ML model was improved from the CL model, with a lower absolute value of log likelihood and a larger pseudo R^2 (or, McFadden R^2) (Domencich and McFadden, 1975). A total of 500 Halton draws were used per iteration in the simulated maximum likelihood estimator which is a reasonable and sufficient number for iteration (Train, 2003). ML results were in line with previous CL results to a large extent. Would-not-buy option and price levels were observed negatively associated with consumers' utility. The NONGMO feature was again preferred.

All signs for the coefficients of nano-attributes remained the same as before, but the significance changed slightly. For example, the coefficient for NANOAG was 1% statistically significant and negative; however, the one for NANOPACK became significant; and insignificant for the coefficient of NANODROPS. Most standard deviation estimates were strongly significant at the 1% significant level, except for the coefficient of NANOPACK. This emphasizes the flexibility of the ML model compared to the CL model. Meanwhile, standard deviations imply taste variations across individuals. Therefore, significant heterogeneities were shown according to the results in ML model.

Table 4.3 Mixed Logit Model Results

Variables	Coeff		Std. Err.	P Value	[95% Conf. Interval]	
MEAN						
BUYNO	-1.8658	***	0.1133	0.00	-2.0879	-1.6437
PRICE	-0.1590	***	0.0060	0.00	-0.1707	-0.1473
NONGMO	0.1567	***	0.0404	0.00	0.0777	0.2358
NANOAG	-0.1509	***	0.0455	0.00	-0.2400	-0.0618
NANOPACK	-0.0809	**	0.0373	0.03	-0.1540	-0.0077
NANODROPS	0.0422		0.0400	0.29	-0.0361	0.1205
Std Dev						
BUYNO	2.7847	***	0.1128	0.00	2.5636	3.0059
NONGMO	0.9782	***	0.0612	0.00	0.2063	0.5745
NANOAG	1.4460	***	0.0634	0.00	0.8075	1.0394
NANOPACK	1.1501		0.0592	0.79	-0.2192	0.1671
NANODROPS	1.2438	***	0.0606	0.00	0.6688	0.8854
Log Likelihood	-7785.278					
Adjusted McFadden R^2 [a]	0.1728					
AIC	15592.56					
BIC	15682.73					

** and *** represent 5% and 1% significance level respectively.
[a] is obtained by one minus the ratio of adjusted unrestricted to restricted log values.

From mean and standard deviation estimates of a normally distributed coefficient, we can calculate the share of respondents in the sample who held a positive or a negative view on that attribute through the normality function $\beta \sim Normal(b, \sigma^2)$. If half of the consumers hold a strong positive view on an attribute but the other half negative, the attribute would be insignificant in a conventional CL model. In that case, respondents' perceptions were equally clustered on both sides of zero, where the average effect is located. Given all information provided in ML model in Table 4.3, the share of consumers that value each random coefficient attribute are provided in Table 4.4.

A total of 74.9% of the respondents had negative values for the Would-not-buy option, indicating a majority of the respondents who would like to make a choice to buy a canola oil product instead of buying nothing. From the mean estimate for the coefficient of NONGMO in the ML model, the sampled respondents preferred canola oil if that was not GM related. However, around 43.6% held a negative opinion on this attribute, which indicate that consumers were familiar with or even accepted the GM feature in their food consumption, and were unwilling to pay more for specialty food items that avoided fortified GM ingredients.

ML model results indicated negative association between the attribute NANOAG and consumers' utility, with significant underlying heterogeneity. It also showed a significantly negative influence for the attribute NANOPACK. However insignificant heterogeneity was observed across the sampled individuals. Lastly, the attribute NANODROPS was insignificant in affecting a canola oil purchase, although significant heterogeneity existed. Furthermore, the splits of positive and negative for the normally distributed coefficients for nano-attributes, displayed in the rest of Table 4.4, served to explain in more detailthe preference variations. For instance, *ceteris paribus*, 55.6% of the respondents did not prefer the NANOAG attribute designed for canola oil where nanotechnology may be adopted during the cultivation or production during the growing of canola seeds; however, the rest 44.4% of the sample viewed it positively. Second, slightly more than half of the respondents (52.8%) held a negative view for attribute NANOPACK, where the canola oil may be bottled or stored in the container with nanotechnology. Third, the attribute NANODROPS indicating that fortified nanodrops were added to canola oil to block cholesterol from being absorbed by human digestive system, was preferred by more than half of the surveyed consumers (51.2%).

Table 4.4 Positive/negative shares of attributes with random coefficients

	Percentage (%)	
Coefficient	**Positive**	**Negative**
BUYNO	25.1%	74.9%
NONGMO	56.4%	43.6%
NANOAG	44.4%	55.6%
NANOPACK	47.2%	52.8%
NANODROPS	51.2%	48.8%

These results indicate that consumers behave differently for new technology applied to food products, either the GM or nanotechnologies. Underlying driving forces for these heterogeneous preferences could be related to consumers' different characteristics including demographics, food shopping habits, risk perception, general acceptance of new technologies, etc. More exploration will be attempted in future work.

Table 4.5 introduces the willingness-to-pay estimates on the basis of the results from the ML model. They were calculated by the nonlinear combination function provided in Stata, using command *nlm* and referring to the expression for WTP_j. The second column depicts the results of the WTP for each attribute, which is the ratio between the marginal utility obtained from that attribute and the coefficient of price. On average, individual would lose $11.73 if he/she did not buy any canola oil in the scenario. Moreover, consumers were likely to pay an average of $0.99 more for a typical bottle of (48 fl. oz.) with the NonGMO attribute. Consumers would be willing to pay $0.95 less per bottle (48 fl. oz. as before) if the canola seeds were produced with nanotechnology. Similarly, consumers would be willing to pay $0.51 less for canola oil packed in a bottle produced with nanotechnology. However, the willingness to pay estimate for the attribute NANODROPS is not significantly different from zero, with a 99% confidence interval of [-$0.23, $0.76].

Table 4.5 Willingness-to-Pay from Mixed Logit Model Results

Variables	Coeff		Std. Err.	P Value	[95% Conf. Interval]	
BUYNO	-$11.73	***	$0.68	0.00	-$13.07	-$10.39
NONGMO	$0.99	***	$0.26	0.00	$0.49	$1.49
NANOAG	-$0.95	***	$0.29	0.00	-$1.51	-$0.39
NANOPACK	-$0.51	**	$0.23	0.03	-$0.97	-$0.05
NANODROPS	$0.27		$0.25	0.29	-$0.23	$0.76

** and *** represent 5% and 1% significance level respectively.

4.6. Conclusion

Using a choice experiment, this study investigated consumers' valuation of canola oil with different types of nanotechnologies applied, as well as in comparison to genetically modified features. The results indicate that NONGMO significantly increased the value of product, however, the three different nano-attributes didn't show consistently results. That's one of the reasons that we investigated differentiated techniques (e.g. NanoAgriculture, NanoPackaging, NanoDrops), which are under different branches of nanotechnology instead of one mingle technology. The study attempted to figure out how different branches of technologies would affect consumers' choices and how much consumers valuate these features. Two logit models were utilized, while the mixed logit model reveals the existence of substantial heterogeneity in consumers' tastes on various attributes, including NONGMO and three nano-attributes (NANOAG, NANOPACK, NANODROPS). Further, the fit of mixed logit model was better than conventional conditional logit model. The results proved the mixed logit model exhibited the higher explanatory power of data.

Estimates for the coefficients in the CL model and estimates for the mean of the random coefficients in the ML model are generally consistent. Consumers valued attribute NANODROPS positively and higher than other nano-attributes for . Actually, consumers do not distinguish between attribute NANOAG nor attribute NANOPACK. A plausible explanation could be that consumers are more acceptapting nanotechnology when they are aware of their explicit benefits. The results indicated that it would be more beneficial for food producer to adventure the potentials that nanotechnology could bring to enhance the well being of consumers.

4.7. Discussions and Implications

This study examines how US consumers may prefer and value various attributes associated with new food technologies, especially nanotechnologies. Given that the majority of past studies on nanotechnology have focused on its general applications, this study provides a timely contribution to the understanding as it is applied to agriculture and food. The willingness to pay valuation with an application of the choice experiment provides a valuable guidance for understanding societal support for food nanotechnologies . As suggested in the results, the number of consumers who are positive toward non-genetically modification is greater than the number of consumers who have negative attitudes. Marketers and policy makers can learn from genetically modification over the last decade, when dealing with other new food technologies.

Consumers response toward the three branches of nanotechnologies: nanoagriculture, nanopackaging and nanodrops, shows their initial recognitions of this new technology. The spilt results highlight the significance of the underlying designing purpose of the attributes. According to this analysis, consumers would like to pay more for nanodrops when they know its functional benefit. Findings from this study will help bridge the gaps between scientific innovation, application of nanotechnology, public policy and industry schemes. A marketer may consider marketing strategies by focusing more on products that would bring direct benefits to human health and may adjust the distribution and merchandising strategy accordingly. Industry producers and marketers should note different consumers may place different values for attributes associated with food nanotechnology, which is not only related to the features of the product itself. The underlying heterogeneities is to be explored in the next chapter. Furthermore, implications from this study could be helpful for scientific development of nanotechnology to find out more practical outlets. Results could assist policy makers in designing regulations in the match of the marketing and industry of nanotechnology in the food industry.

Chapter 5 Heterogeneous Consumer Preference for Nanofoods

5.1. Introduction

Consumer acceptance of new food technologies depends not only on the features and advances of the technology but also on consumers' characteristics, demographics and socio-psychological points of view. Agriculture and food applications of nanotechnology will have an increasingly important impact on people's lives, due to the fast growth of nanotechnology development. It is therefore necessary to pay more attention and do more research on public perception of nanotechnology. Recent studies focused on public support and knowledge deficit issues regarding nanotechnology (Bieberstein, et al., 2011, Einsiedel, 2005, Hart, 2009, Siegrist, et al., 2007, Siegrist, et al., 2007). These studies targeted at consumers' initial recognition to nanotechnology, as well as the in willingness-to-pay (WTP) estimate for the associated new attributes. It is an important first step, because consumers' acceptance and willingness to pay are necessary conditions for adoption of potentially costly new attributes. Moreover, the underlying reasons for consumers to be willing to pay for new attributes are worthwhile. Agribusinesses and policy makers can benefit from understanding why consumers might be willing to pay differently for such attributes.

Research about consumers' preferences has been applied to explain the disruption in consumption regarding food safety (Brewer and Rojas, 2008, Wilcock, et al., 2004). In addition, perceived risk and perceived benefit have been widely used in the literature to examine taste variations (Dosman, et al., 2001, Finucane and Holup, 2005). Adaption of these two frameworks could be helpful in unveiling the reasons why consumers are willing to pay for new food technology attributes and where potential food safety issues may be of concern. As a result, we investigated both socio-demographic information and socio-psychological determinants for consumer preference and willingness-to-pay for new food technologies. Furthermore, this chapter aims to detect the source of taste heterogeneities across individuals pertaining to different canola oil products and other general food items. This is in addition to the previous chapters of this dissertation where we examined consumer preference to attributes associated with different nanotechnologies and GM based on Random Utility theory.

5.2. Literature Review

One of the key determinants for the success of a new technology is societal support (Frewer, et al., 2004, Rowe, et al., 2004). A number of previous studies had made efforts to gain insights about societal response to new food technologies (Bainbridge, 2002, O'Hara, et al., 2006, Ronteltap, et al., 2007). It is also suggested that consumers are motivated by perceived risk, rather than the actual probability of risk itself (Slovic, 1987, Starr, 1969). Therefore, scrutinizing the willingness-to-pay for new food technologies in the light of risk perception would be more realistic and provide useful information for marketers and policy makers thinking of investing in new food technologies. Perceived benefit of new food technologies is a driving force of consumer preference. Siegrist (2000b, 2000a) suggested that perceived risks were strongly correlated with perceived benefits. Since both risk and benefit perceptions could conceivably influence consumers' purchase decisions, it is necessary to include both risk and benefit perception frameworks. To achieve this goal, several questions pertaining consumers' perception of new food technologies were in the survey before choice experiments.

Ronteltap et al (2011) summarized recent studies in Europe and US about social response to nanotechnology. They emphasized the importance of societal support to the adoption of this technology. Nanotechnology is an emerging technology and vulnerable to societal perception, which may hinder its further development. Our analysis contributes to the literature by combining both qualitative and quantitative analyses about nanotechnology. Moreover, we did not treat food nanotechnology as a single technology but as different branches under the nanotechnology family, especially when applied to food industry. In addition to the survey questions on new technologies, we designed more Likert Scale questions which are specific to three types of nanotechnologies: nanoagriculture, nanopackage and nanodrops. Specifically, the examined attributes in this dissertation are: *nanoagriculture* refers to the technology applied during the growing of canola seeds; *nanopackage* refers to techniques used for the containers or bottles to pack canola oil final product or other means during delivery; *nanodrops* refers to canola oil produced with nano-engineered content, which is directly applied into the content of final products.

Besides the *perceived risk* and *perceived benefit* associated with new technologies, other individual specific characteristics, for instance *individual differences*, *attitude*, *health impact* and *environmental impact*, were observed to be the most frequently investigated determinants in the literature (Gupta, et al., 2011). For example, researchers have found that gender was an important factor in evaluating of technological risk for food hazards (Frewer, 1999, Siegrist, et al., 2003), where men were less worried about a range of different food risks compared to women. Women were more concerned about natural and technological food risks. In a study of nanotechnology, Bieberstein et al (2011) surveyed people in a German municipal area and found that men had a more positive attitude compared to women towards science and technology and men were more familiar with nanotechnology than women. Education (Wilcock, et al., 2004) was also examined to explain consumers' acceptance of new technology. In the following sections of this chapter, we will introduce other demographic information and related results.

5.3. Descriptive Statistics

5.3.1. Socio-economic Statistics

Table 5.1 presents the summary statistics for demographic variables used in this chapter. In comparison to the US Census (or the Current Population Survey in 2012), the sample is closely representative. In addition to typical demographic variables (Age, Household Size, Household Income, Education, Marital Status, Male and Employment Status), other individual difference factors were also examined in this chapter: number of children, location, affiliations to environmental association, and frequency of label reading. As depicted, about 6 percent of the sample respondents were members of some environment friendly association. A total of 75 percent of the respondents live in a city or suburb area. On average, respondents reported that they occasionally (correspondently in the table, 1=Never, 2=rarely, 3=Occasionally, 4=Regularly) read labels when buying food products.

Table 5.1 Descriptive Demographic Statistics

	Mean	Std. Dev.	Min	Max	**US Census**
Age (year)	40.8	17.0	18	89	**37.2**[b]
Household Size	2.7	1.45	1	13	**2.55**[a]
Community	0.75	0.43	0	1	-
Household Income ($10,000)	6.52	4.69	1	15	**5.14**[b]
Education (year)	15	3	0	20	**12**[b]
Child	0.55	1.01	0	8	-
Marital Status	0.46	0.50	0	1	-
Male	0.56	0.50	0	1	**0.49**[b]
Readlabels	3	1	1	4	-
Member	0.06	0.24	0	1	
Employment Status	0.59	0.49	0	1	-

[a] US Census

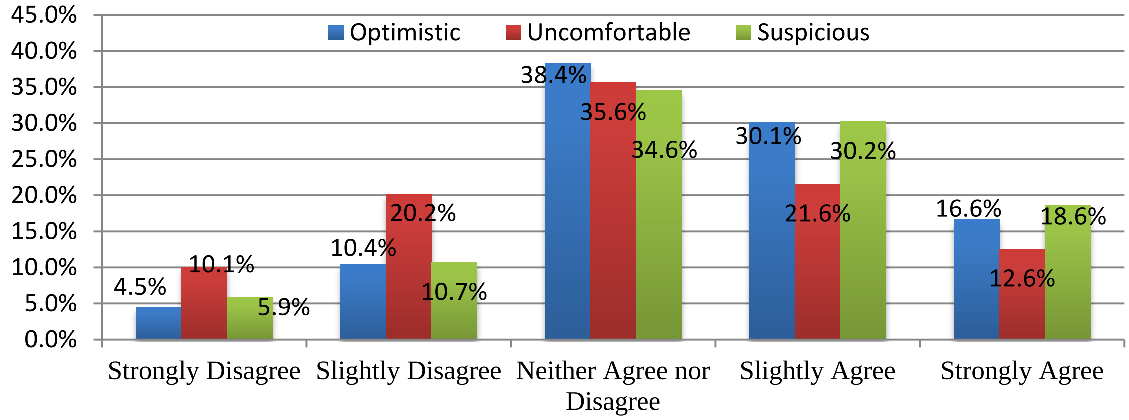
[b] Current Population Survey 2012 Annual Social and Economic Supplement, formerly called the March Supplement, http://www.census.gov/hhes/www/cpstables/032012/hhinc/hinc01_000.htm

5.3.2. Perception Statistics

Figure 5.1 presents the answers to different statements pertaining to new technologies as applied to food products. The question asked in the questionnaire was: "Suppose you have to choose food products produced with new technology. Which statement will be the BEST to describe your feeling?" The three statements about the respondents' perceptions were: optimistic (*"I am optimistic about new technology applied in food"*), uncomfortable (*"I feel uncomfortable regarding new food technology"*) or suspicious (*"As a result of food safety incidents, I am suspicious about the safety of certain food products"*). The questions were designed using the Likert Scale format with five levels: Strongly Disagree, Slightly Disagree, Neither Agree nor Disagree, Slightly Agree and Strongly Agree.

In general, slightly more than one third of the respondents were among the golden mean referring to all questions, not favoring to either side especially. Around 47 percent of the sampled consumers were optimistic about new technologies applied in food, while 15 percent of them were not. Meanwhile, 49 percent of the respondents said they were suspicious of foods' safety, due to previous food safety incidents; and 17 percent were not suspicisous. In comparison, about 34 percent of the respondents felt uncomfortable about new food technology but 30 percent were not.

Figure 5.1 Perception upon Food Products Produced with New Technologies (%)



Two groups of perception questions referred to specific food technologies: irradiation, food additives, genetical modification and three types of nanotechnologies. These questions asked respondents to rate the risks or benefits on human health and to the environment. The original statement used in the survey was: "Modern agricultural technology enables a variety of ways to produce and prepare food. We are interested in knowing how you think about the relative benefits and risks of different types of technologies given below, in respect to Human Health and the Environment. Please indicate in each category below the impact of different technologies on Human Health (or Environment)." Respondents' answers were distributed as shown in figure 5.2a and 5.2b.

Figure 5.2a Impact on Human Health

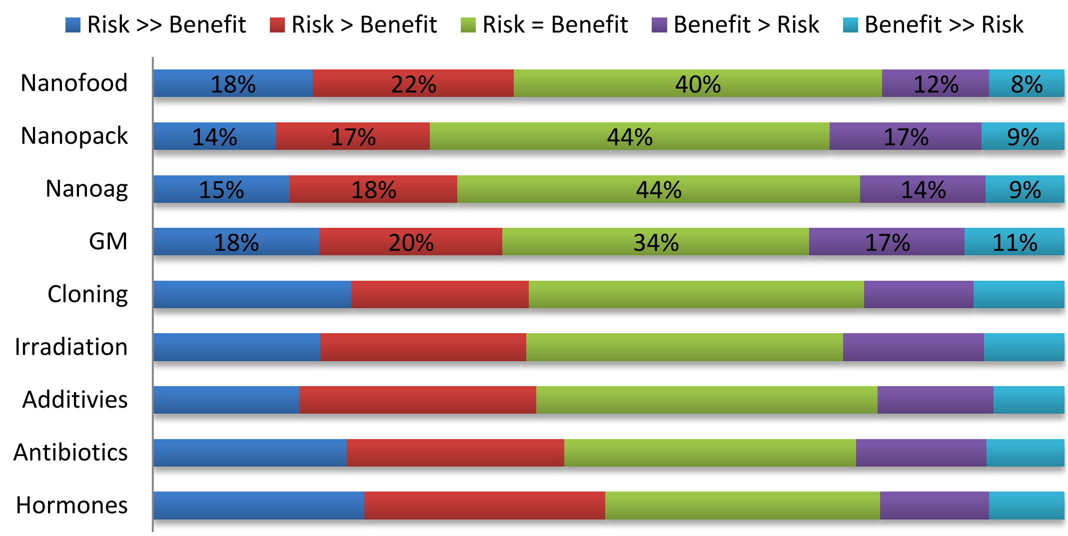
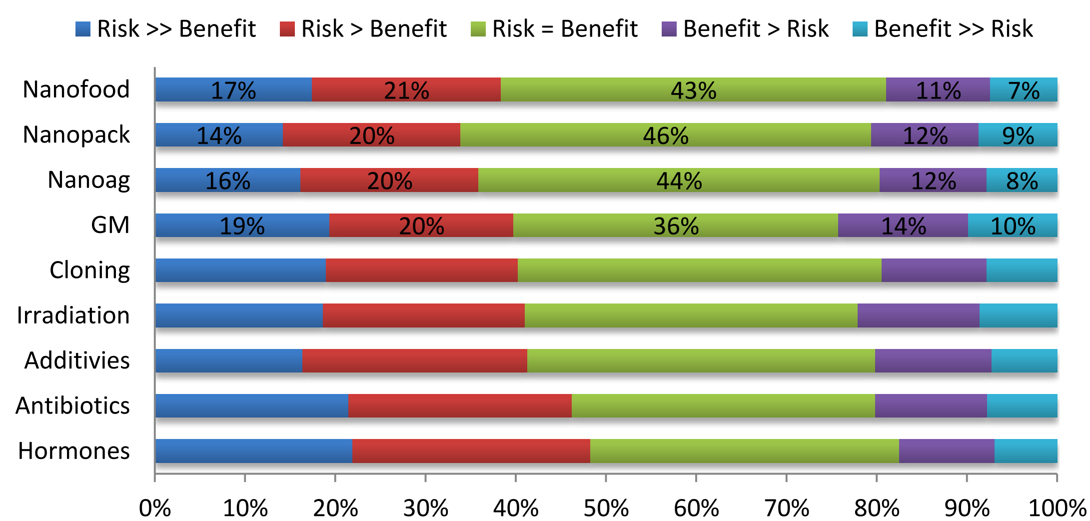


Figure 5.2b Impact on Environment



Overall, consumers believed that food technology is risky according to the results in both figures. Genetical modification (GM) is the most recent controversial new technology application to foods. About 40 percent of the sampled respondents thought genetical modification would bring more risks than benefits to either the human body or the environment, while about 30 percent were neutral.

When it comes to nanotechnology, over 40 percent of the surveyed consumers rated all nanotechnologies as being equal on risks and benefits. This relatively large portion of neutrality about nanotechnology suggests that we have a window of opportunity for educating the public about risks and benefits. Among the three nanotechnologies: ‘Nanofood’ was observed to be the most risky technology. And, the ‘Nanopack’ technology was the least risky in respondents’ view.

5.4. Econometric Models

Consumer preferences models for canola oil and with different technologies, , are presented in this section. The utility of consumer *i* associated with alternative *j* in choice scenario *t* in the choice experiment is given in Random Utility Models (McFadden, 1974) as followed:

$$Model\ \#1:\ \mathrm{U_{ijt}} = \alpha * \mathrm{price_{ijt}} + \boldsymbol{X}_{ijt}\boldsymbol{\beta} + \boldsymbol{DX}_i\boldsymbol{\delta} + \varepsilon_{ijt}$$

$$Model\ \#2:\ \mathrm{U_{ijt}} = \alpha * \mathrm{price_{ijt}} + \boldsymbol{X}_{ijt}\boldsymbol{\beta} + \boldsymbol{PX}_i\boldsymbol{\mu} + \varepsilon_{ijt}$$

$$Model\ \#3:\ \mathrm{U_{ijt}} = \alpha * \mathrm{price_{ijt}} + \boldsymbol{X}_{ijt}\boldsymbol{\beta} + \boldsymbol{DX}_i\boldsymbol{\delta} + \boldsymbol{PX}_i\boldsymbol{\mu} + \varepsilon_{ijt}$$

As before, the price coefficient α is assumed as a fixed parameter rather than a random parameter to avoid unrealistic welfare measures associated with a random price parameter (Meijer and Rouwendal, 2006, Olsen, 2009). The random parameter model is the more capable choice models in capturing heterogeneities (Train, 2003). Particularly, coefficients in vector $\boldsymbol{\beta}$ are assumed to be random and independently normally distributed. There is no prior theory to suggest any specific form for this distribution. Attributes in the vector $\boldsymbol{X}_{ijt}$ where $\boldsymbol{\beta}$ is associated with attributes in the choice experiment as described in previous chapters:

$$\boldsymbol{X}_{ijt} = [BUYNO, NONGMO, NANOAG, NANOPACK, NANODROPS]_{ijt}$$

Moreover, attributes $NONGMO, NANOAG, NANOPACK, NANODROPS$ are interacted with demographics, referring to vector $\boldsymbol{DX}_i$ in model 1. Past studies have examined demographic variables including age, gender and education and consumer tastes to detect consumer preference heterogeneity in food and food related grocery items (Carpenter and

Moore, 2006, Dong and Stewart, 2012, Gaudagni and Little, 1992, Status, 2009, Stone, 1995). The coefficient vector $\boldsymbol{\delta}$ associated with the interaction terms accounts for the contribution of related interactions to the utility function. Although other interaction terms not included may have some impacts on the utility, we limit the model to the interactions between attributes, especially nano-attributes examined in this chapter to keep the analysis concise. The base cases in this study are "*TYPICAL* canola oil items with *NO NANO-ATTRIBUTES* included in production, delivery, package or final product". To be noted, currently nearly 90 percent of this 'typical' canola oil on the US market is produced from genetical modified (GM) canola crops (Biello, 2010, Johnson, et al., 2008). We did present this information in the survey in order to assist respondents' choices.

Model 2 depicts a different group of interactions between attributes in vector $\boldsymbol{PX}_i$, where vector $\boldsymbol{P}$ consists of perception and attitude of risks and benefits. This aims to investigate how consumers' perception and attitude toward new technologies, including both GM and nanotechnologies, will affect consumers' choices of food products to which these techniques are applied. All variables and corresponding descriptions are provided in Table 5.2.

Table 5.2 Variables and Descriptions

Variables		Descriptions	
Nano-attributes	PRICE	Continuous, $ per bottle of 48 fl. oz.	
	NONGMO	Dummy, =1 if attribute presented	
	NANOAG		
	NANOPACK		
	NANODROPS		
Demographics	AGE	Continuous	
	HHSIZE	Continuous, household size	
	COMM	Dummy, =1 if live in city or suburb area	
	INCM	Continuous, $10,000	
	EDUYEAR	Continuous	
	CHILD	Continuous, number of child in the family	
	MARRIED	Dummy, =1 if married	
	MALE	Dummy, =1 if male	
	READLABELS	Category, =1 if never read labels, =4 if regularly read labels	
	MEMBER	Dummy, =1 if associated to any environmental society	
	EMPL	Dummy, =1 if employed	
Perception	HH	Category, =1,2,3,4,5: =1 if rated the impact of related technology on ***human health*** is "risks much greater than benefits" =5 i f rated the impact of technology on ***human health*** is "benefits much greater than risks"	
	EN	Category, =1,2,3,4,5: =1 if rated the impact of technology on ***environment*** is "risks much greater than benefits" =5 i f rated the impact of technology on ***environment*** is "benefits much greater than risks"	
Attitude	OPT	Category, =1,2,3,4,5 =1 if strongly disagree =5 if strongly agree	"I am optimistic about new technology applied in food"
	UN		"I feel uncomfortable regarding new food technology"
	SUS		"As a result of food safety incidents, I am suspicious about the safety of certain food products"

Note that the perception and attitude of risks and benefits variables are both obtained from Likert Scale questions and coded from 1 to 5. In the perception group, 1 reflects very risky and 5 reflect very beneficial. While in the attitude group, 1 indicates strongly disagree and 5 indicates strongly agree. For instance, an individual who rated 1 for the statement “I am optimistic about new technology applied in food” suggested that he/she was not at all positive about new technology. If he/she rated 4 for statement “As a result of food safety incidents, I am suspicious about the safety of certain food products”, he/she was slightly strongly negative about any new technology. Summarizing the above description, choice probability functions are updated here as,

$$Model\ \#1:$$

$$\pi_{ijt} = \int \frac{exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta} + \boldsymbol{DX}_i\boldsymbol{\delta}\right)}{\sum_{k=1}^{J} exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta} + \boldsymbol{DX}_i\boldsymbol{\delta}\right)} h(\boldsymbol{\beta})d\boldsymbol{\beta}, \text{where } \boldsymbol{\beta} \sim Normal(\boldsymbol{\theta}^{\mathbf{1}}, \Omega^{\mathbf{1}})$$

And,

$$Model\ \#2:$$

$$\pi_{ijt} = \int \frac{exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta} + \boldsymbol{PX}_i\boldsymbol{\mu}\right)}{\sum_{k=1}^{J} exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta} + \boldsymbol{PX}_i\boldsymbol{\mu}\right)} h(\boldsymbol{\beta})d\boldsymbol{\beta}, \text{where } \boldsymbol{\beta} \sim Normal(\boldsymbol{\theta}^{\mathbf{2}}, \Omega^{\mathbf{2}})$$

And,

$$Model\ \#3:$$

$$\pi_{ijt} = \int \frac{exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta} + \boldsymbol{DX}_i\boldsymbol{\delta} + \boldsymbol{PX}_i\boldsymbol{\mu}\right)}{\sum_{k=1}^{J} exp\left(\alpha * \text{price}_{\text{ijt}} + \boldsymbol{x}_{ijt}\boldsymbol{\beta} + \boldsymbol{DX}_i\boldsymbol{\delta} + \boldsymbol{PX}_i\boldsymbol{\mu}\right)} h(\boldsymbol{\beta})d\boldsymbol{\beta}$$

$$\text{where } \boldsymbol{\beta} \sim Normal(\boldsymbol{\theta}^{\mathbf{3}}, \Omega^{\mathbf{3}})$$

Therefore, the utility maximizing problem becomes the problem of maximizing the likelihood of realizing the observed choices, which are chosen not only because of attributes but also because of interacted effects with consumers’ demographics, perception and attitudes related to new technologies implemented in food products.

Although interpretation is feasible in a mixed logit model setting, we also presented the interpretation of the results in the more meaningful form of marginal willingness-to-pay (WTP). To account for non-linearity, the WTP estimates and standard errors were produced in STATA with command *nlm*. Marginal individual willingness-to-pay estimates based on mixed logit model is calculated as:

$$WTP_{j*D} = -1 * \frac{\delta_{j*D}}{\alpha}$$

$$or, WTP_{j*P} = -1 * \frac{\mu_{j*P}}{\alpha}$$

$$j = [BUYNO, NONGMO, NANOAG, NANOPACK, NANODROPS]$$

$$D = [AGE, HHSIZE, COMM, INCM, EDUYEAR, CHILD,$$

$$MARRIED, MALE, READLABELS, MEMBER, EMPL]$$

$$P = [HH, EN, OPT, UN, SUS]$$

5.5. Econometric Estimation Results

The results of the mixed logit models associated with the previous two random utility models were included in Table 5.3 and 5.4 respectively. The efficiency and advance of mixed logit model could be attributed to the inclusion of unobserved preference heterogeneities, as evidenced by multiple significant estimated standard deviations for the random coefficients in all models. All model results were produced with Stata 12.0, and using 500 Halton draws (Train, 2003). Model fitness criteria were provided as log likelihood function value, Adjusted McFadden R^2 and AIC, BIC information indicators. The values of adjusted McFadden R^2 are 0.1620 and 0.1494 separately from both models, which indicated somewhat reasonable explanatory power for mixed logit model. Variables PRICE and BUYNO were strongly significantly and negative in both models, indicating negative associations with utility. That is, consumers would lose utility by either choosing a product with higher retail price or by refusing to choose any non-emptyoptions.

5.5.1. Interactions with Demographics

Table 5.3 depicts the results for the mixed logit model when the key attributes interactwith socio-economic variables (i.e., AGE, HHSIZE, INCM, EDUYEAR, etc.). In the results from the basic mixed logit model in chapter 4, significant coefficients were obtained for all attribute variables except NANOPACK. In contrast, only the coefficient for NANODROPS was observed to be significantly positive in model #1 with interactions; other attributes did not have significant mean estimates. However, results in the groups of standard deviation estimates revealed strong significance at the 1% level for all other attributes (NONGMO, NANOAG) and for the would-not-buy option (BUYNO), which suggested significant heterogeneities across individuals.

No significance was found amongst interactions between the attribute NONGMO and demographics, except for CHILD. That is, the more children a family has, the less likely the household would purchase non-GMO canola oil, relative to a GM product. Another two determining factors were READLABELS and MEMBER, both of which had coefficients significant at the 5% level. The more frequently an individual read product labels when buying, the more likely he/she might choose non-GMO canola oil. Furthermore, consumers might be more likely to buy non-GMO item when they are affiliated to an environmental association.

When it comes to nano-attributes, it was revealed that the prominent determining factors affecting consumers' buying behavior were consumers' age, living location, and employment status, corresponding to variables AGE, COMM and EMPL. As suggested, senior consumers were less likely than other consumers to buy canola oil produced via nanotechnology agriculture or with nanodrops. However, no significance was found for the coefficient of the attribute of NANOPACK when interacted with AGE. It was observed that coefficients were all significantly positive for nano-attributes interacted with variable COMM. The results implied that consumers who lived in cities or suburb areas might be more likely to accept food nanotechnologies. Others significant determinants found in the results were frequency of reading product labels (READLABELS), environmental friendly affiliations (MEMBER), and household income (INCM) as given in the table.

Table 5.3 Mixed Logit Model Results with Socio Demographic Interactions

Main Effect

Mean		Std. Dev.	
NONGMO	-0.1294	NONGMO	0.3718***
	(0.3116)		(0.0983)
NANOAG	0.0121	NANOAG	0.9170***
	(0.3529)		(0.0588)
NANOPACK	-0.0167	NANOPACK	-0.0152
	(0.2861)		(0.0960)
NANODROPS	0.5510 *	NANODROPS	0.7549***
	(0.3090)		(0.0554)
BUYNO	-1.8714 ***	BUYNO	2.7279***
	(0.1114)		(0.1123)
PRICE	-0.1600 ***		
	(0.0060)		

Average Values: AGE=40.8; HHSIZE=3; COMM=1; INCOM=6.5($65000); EDUYEAR=15; CHILD=1; MARRIED=1; MALE=1; READLABELS=3; MEMBER=0; EMPL=1

Demographic Interactions

NONGMO* AGE	-0.0005	NANOAG* AGE	-0.0039*	NANOPACK* AGE	0.0000	NANODROPS* AGE	-0.0114***
	(0.0027)		(0.0031)		(0.0025)		(0.0027)
NONGMO* HHSIZE	0.0633	NANOAG* HHSIZE	-0.0569	NANOPACK* HHSIZE	-0.0194	NANODROPS* HHSIZE	-0.0073
	(0.0410)		0.0457		(0.0370)		(0.0402)
NONGMO* COMM	-0.0150	NANOAG* COMM	0.1265*	NANOPACK* COMM	0.1361	NANODROPS* COMM	0.2374***
	(0.0953)		(0.1086)		(0.0882)		(0.0954)
NONGMO* INCM	-0.0061	NANOAG* INCM	0.0074	NANOPACK* INCM	0.0163*	NANODROPS* INCM	0.0134
	(0.0105)		(0.0118)		(0.0097)		(0.0104)

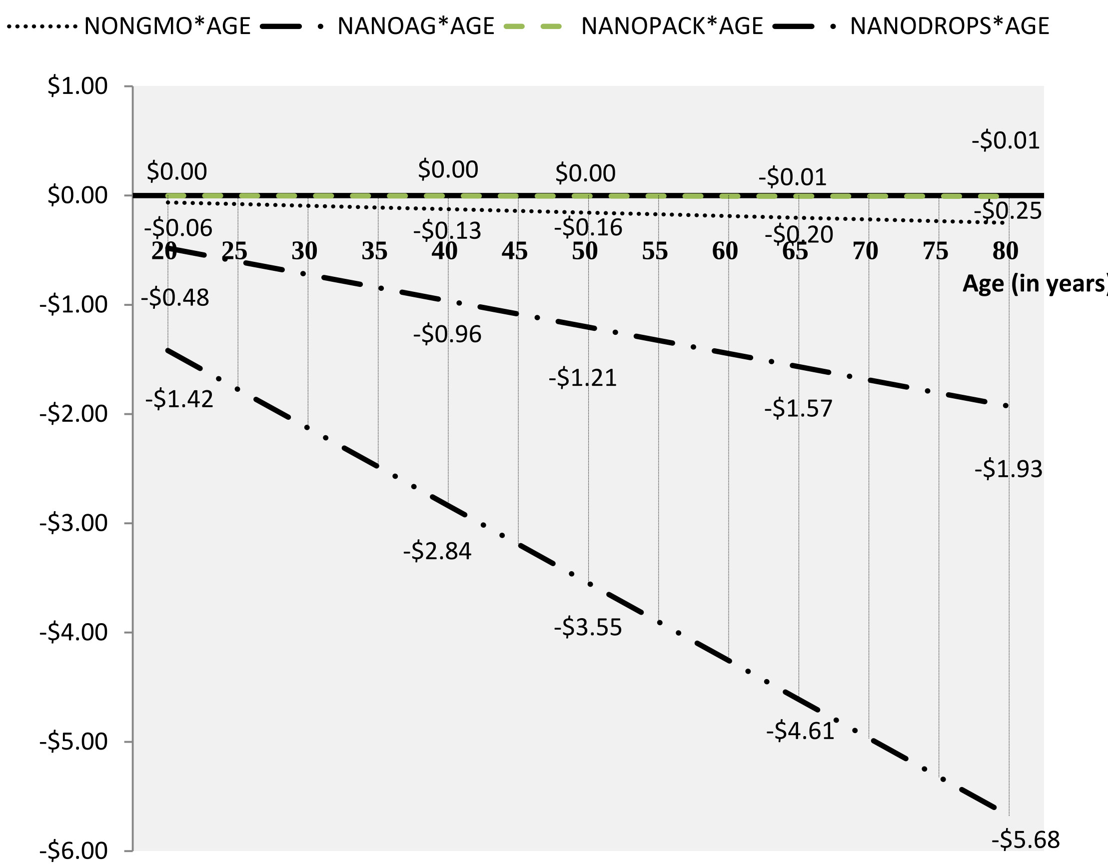
Table 5.3 (con't)

NONGMO* EDUYEAR	-0.0155	NANOAG* EDUYEAR	-0.0115	NANOPACK * EDUYEAR	-0.0120	NANODROPS* EDUYEAR	-0.0231
	(0.0164)		(0.0183)		(0.0148)		(0.0160)
NONGMO* CHILD	-0.1010*	NANOAG* CHILD	0.0866	NANOPACK * CHILD	-0.0140	NANODROPS* CHILD	0.0403
	(0.0578)		(0.0647)		(0.0526)		(0.0569)
NONGMO* MARRIED	0.0047	NANOAG * MARRIED	0.0298	NANOPACK * MARRIED	0.0159	NANODROPS* MARRIED	0.0526
	(0.0966)		(0.1083)		(0.0883)		(0.0952)
NONGMO* MALE	0.0949	NANOAG* MALE	0.1283	NANOPACK * MALE	-0.0206	NANODROPS* MALE	-0.0754
	(0.0832)		(0.0933)		(0.0759)		(0.0818)
NONGMO* READLABELS	0.0997**	NANOAG * READLABELS	-0.0145	NANOPACK * READLABELS	-0.0230	NANODROPS* READLABELS	0.0484
	(0.0497)		(0.0564)		(0.0461)		(0.0496)
NONGMO* MEMBER	0.3069*	NANOAG * MEMBER	-0.0744	NANOPACK * MEMBER	-0.1703	NANODROPS* MEMBER	-0.0724
	(0.1593)		0.1804		(0.1464)		(0.1578)
NONGMO* EMPL	0.1409	NANOAG* EMPL	0.1330	NANOPACK* EMPL	0.0779	NANODROPS* EMPL	-0.1846**
	(0.0914)		(0.1025)		(0.0833)		(0.0901)
Log Likelihood	**-7748.359**	**Adjusted McFadden R^2**	**0.1603**	**AIC**	**15606.72**	**BIC**	**16057.6**

Note: ***,**,* indicate significant at the 1%, 5%, and 10% significance levels respectively. Standard Error are in parentheses. Results produced with STATA 12.0, 500 Halton Draws.

Individual willingness-to-pay estimates were found to reflect consumers' heterogeneous preferences based on the above mixed logit model. As shown in figure 5.3, the unit price for typical canola oil was not significantly different across individuals in different age groups for NONGMO, NANOAG, or NANOPACK. However, a significant trend was seen in the item if nanodrops were added in the product. The older the consumer is, the less might he/she pay for such product, which is shown as the downward line in the graph.

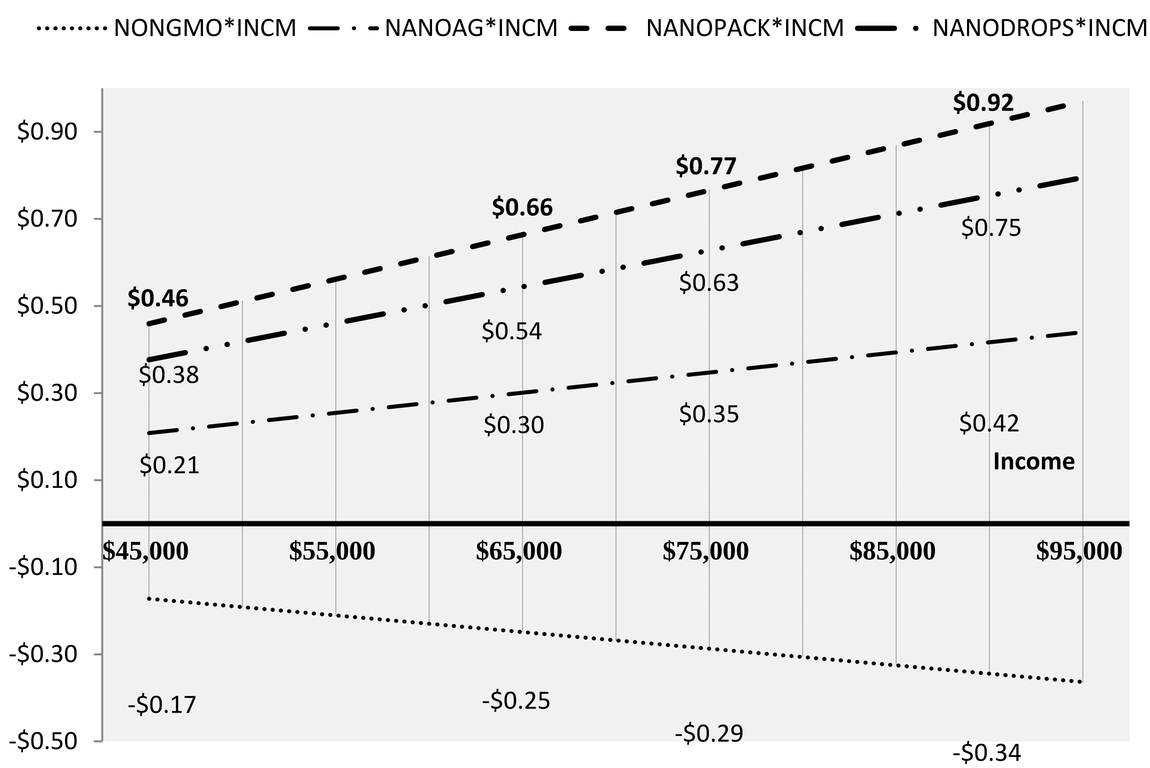
Figure 5.3 Individual Willingness-to-Pay Estimates Interacted with AGE Based on Model with only Demographic Interactions



***Only estimate in the group of NAONODROPS were significant at 1%**

Another factor lead to heterogeneity might be household annual income, as shown in figure 5.4 in below. No significant differences were found amongst respondents for most attributes except NANOPACK, where the product was packed in specialized bottle or other containers developed with nanotechnology. Significant positive WTP was observed indicated by an ascending trend with higher income level. For example, for a household family who earn $95000 a year might value a nanotechnology developed bottle of canola oil at $0.92 more than a typical bottle in a grocery store.

Figure 5.4 Individual Willingness-to-Pay Estimates Interacted with INCOME Based on Model with only Demographic Interactions



*Only estimate in the group of NAONOPACK were significant at 10%

5.5.2. Impact of Perceptions and Attitudes

Next, the impacts of consumers' perception and attitude on their preference toward food technology attributes were examined. Estimated results are provided in Table 5.4 and relate to the variables listed in Table 5.2. The coefficients for PRICE and BUYNO were in line with previous results were negative and significant. The coefficient for NONGMO was positive. All coefficients for nano-attributes were significant and negative at the 1% level, compared to previous results where the coefficient for NANOPACK was insignificant and positive for NANODROPS. Moreover, standard deviation estimates were all significant except the one for variable NANOPACK, which was the same as in the previous results.

Individual effects with attributes interacting with different perception variables are depicted in the bottom part of the table. However, no significances were found for the coefficients of NONGMO groups. That is, consumers were consistently positive about the non-genetically modified products. More interesting results were found in the nano-attribute groups. For example, respondents who saw the benefit of nanotechnology to the final product were willing to pay more for the canola oil with NANODROPS. Likewise, respondents who expected nanotechnology applied during cultivation would pay more for the NANOAG canola oil.

Table 5.4 Mixed Logit Model Results with Perception and Attitude Interactions

Main Effect							
PRICE	-0.1605*** (0.0060)	*Std. Dev.*					
NONGMO	0.3096* (0.1901)	NONGMO	0.3466*** (0.1046)				
NANOAG	-1.0501*** (0.2134)	NANOAG	0.8761*** (0.0592)				
NANOPACK	-0.5935*** (0.1774)	NANOPACK	-0.0243 (0.0997)				
NANODROPS	-0.8244*** (0.1887)	NANODROPS	0.7588*** (0.0554)				
BUYNO	-1.8667*** (0.1093)	BUYNO	2.6366*** (0.1088)				
Perception and Attitude Interactions							
NONGMO*HH	-0.0572 (0.0479)	NANOAG*HH	0.0820 (0.0611)	NANOPACK*HH	0.0234 (0.0496)	NANODROPS*HH	0.1351** (0.0548)
NONGMO*EN	-0.0687 (0.0485)	NANOAG*EN	0.2338*** (0.0618)	NANOPACK*EN	0.0745 (0.0500)	NANODROPS*EN	0.0710 (0.0558)
NONGMO*OPT	-0.0229 (0.0430)	NANOAG*OPT	0.1556*** (0.0478)	NANOPACK*OPT	0.1060*** (0.0393)	NANODROPS*OPT	0.1602*** (0.0428)
NONGMO*UN	0.0308 (0.0414)	NANOAG*UN	-0.0876* (0.0467)	NANOPACK*UN	-0.0346 (0.0391)	NANODORPS*UN	0.0051 (0.0420)
NONGMO*SUS	0.0573 (0.0442)	NANOAG*SUS	-0.0844* (0.0497)	NANOPACK*SUS	-0.0105 (0.0414)	NANODROPS*SUS	-0.0882** (0.0446)
Log Likelihood	**-7688.117**	**McFadden R^2**	**0.1494**	**AIC**	**15438.2**	**BIC**	**15692.4**

Note: ***,**,* indicate significant at the 1%, 5%, and 10% significance levels respectively. Standard Error are in parentheses. Results produced with STATA 12.0, 500 Halton Draws.

Variables OPT, UN and SUS referred to consumers' attitudes and perceptions toward new food technology in general. For HH and EN, consumers ranked specific technologies (genetically modification, nanotechnology in agriculture, nanotechnology in packaging and nanotechnology in final product). Here, respondents who were highly optimistic about new food technologies showed significantly positive attitudes to all nanotechnologies. On the other hand, respondents who were suspicious about new food technologies due to food safety concerns, were pessimistic about nanotechnologies. Specifically, the more the respondents worried or were suspicious about new food technology, the less likely they will buy a product featured with NANOAG or NANODROPS. However, no significant differences were noticed between respondents' anxiety about new food technology and nanotechnology package.

Table 5.5 presents individual willingness-to-pay estimates pertaining to different perceptions on both generic new technologies and the specific technologies that have been addressed in this study. Using a rating of 3 as neutral, the respondents were divided into different groups: optimistic, pessimistic and neutral attitudinal about new food technologies. Respondents who rated new food technologies as a 5 were considered optimistic; meanwhile, those who rated 1 were classified as pessimistic and those who rated 3 were neutral. We kept it consistent for "perception on generic new food technology", where the optimistic consumers were those who rated 5 for the statement of OPT and 3 for UN and 1 for SUS. Similarly, the pessimistic consumers referred to those who rated 1 for OPT, 3 for UN and 5for SUS.

Table 5.5 Individual Willingness-to-Pay Estimates according to different perception based on Mixed Logit Model interacting with only perceptions interactions

	PERCEPTION on Specific New Food Technology					
	Optimistic	p value	***Neutral***	p value	***Pessimistic***	p value
	HH=5,EN=5		*HH=3,EN=3*		*HH=1,EN=1*	
NONGMO*	-$3.92***	0.00	-$2.35***	0.00	-$0.78***	0.00
	($1.21)		($0.72)		($0.24)	
NANOAG*	$9.84***	0.00	$5.90***	0.00	$1.97***	0.00
	($1.50)		($0.90)		($0.30)	
NANOPACK*	$3.05***	0.01	$1.83***	0.01	$0.61***	0.01
	($1.23)		($0.74)		($0.25)	
NANODROPS *	$6.42***	0.00	$3.85***	0.00	$1.28***	0.00
	($1.30)		($0.78)		($0.26)	

	PERCEPTION on Generic New Food Technology					
	Optimistic	p value	***Neutral***	p value	***Pessimistic***	p value
	OPT=5,UN=3,SUS=1		*OPT=3,UN=3,SUS=3*		*POPT=1,UN=3,SUS=5*	
NONGMO*	$0.22	0.89	$1.22	0.24	$2.22**	0.05
	($1.53)		($1.04)		($1.12)	
NANOAG*	$2.68	0.12	-$0.31	0.79	-$3.30***	0.01
	($1.71)		($1.15)		($1.25)	
NANOPACK*	$2.59*	0.07	$1.14	0.23	-$0.31	0.76
	($1.41)		($0.95)		($1.03)	
NANODROPS *	$4.53***	0.00	$1.44	0.16	-$1.65	0.14
	($1.53)		($1.03)		($1.12)	

Note: *****,**,*** indicate significant at the 1%, 5%, and 10% significance levels respectively. Standard Error are in parentheses.

For the NONGMO category, consumers were asked to rate the risk and benefit of products to human health and environment. Therefore, the WTP estimates for NONGMO was conditional on consumers' perception of the genetically modification technology. The higher score the respondent gave, the more beneficial he/she might relative to genetically modification applied to food products.

When specifying nanotechnology into different branches, all coefficients for the interactions between nano-attributes and perception variables were 1% significant and positive. Consumers who were most optimistic were willing to pay a premium for canola oil; $9.84 more for NANOAG; $3.05 more for NANOPACK; $6.42 more for NANODROPS. However, when considering consumers' perception of new food technologies genenrally-without spelling out the technologies correctly No result was significant. Future research about consumers' acceptance and information provided is required in order to improve the understanding.

5.5.3. Full model with all interactions and Total WTP Estimates

This section extended the previous two sections and combines both demographic and perception information, to derive total willingness-to-pay estimates. The mixed logit results are presented in Table 5.6. The results were generally consistent with the previous two model presented in Table 5.3 and 5.4. As all possible interaction terms were included in the full model, the total willingness-to-pay is calculated as:

$$WTP_j = -1 * \frac{\beta_j + \bar{D}\delta + P\mu}{\alpha}$$

$$j = [BUYNO, NONGMO, NANOAG, NANOPACK, NANODROPS]$$

$$\bar{D} = \boldsymbol{Average\ value\ of}\ [AGE, HHSIZE, COMM, INCM, EDUYEAR,$$

$$CHILD, MARRIED, MALE, READLABELS, MEMBER, EMPL]$$

$$P = [HH, EN, OPT, UN, SUS]$$

Results are given in Table 5.7 (and figure 5.5) according to three different groups of consumers' perceptions about new food technologies. We redefined three groups by combining respondents' perceptions on both specific and generic new food technologies.

Consumers would pay $3.80 more for NONGMO featured canola oil on average, if they were not at all optimistic about new food technology, and were very suspicious of food item as result of certain food safety incidents, and they also thought genetical modification might bring much more risks than benefits to human health and environment. These consumers were likely to pay $7.07 less for a typical bottle of canola oil if nanotechnology was applied to canola seed; $3.00 less for if nanotechnology was used in creating the bottle or containers; $5.80 less if nanodrops was added to the final canola oil product. We may refer to this group of consumers as pessimistic.

Table 5.6 Full Mixed Logit Model Results with both Demographics and Perceptions

Main Effect

Mean		Std. Dev.	
NONGMO	0.0184	NONGMO	-0.3561***
	(0.3413)		(0.1000)
NANOAG	-0.6164	NANOAG	0.8815***
	(0.3821)		(0.0591)
NANOPACK	-0.3259	NANOPACK	-0.0059
	(0.3165)		(0.1006)
NANODROPS	-0.0113	NANODROPS	-0.7471***
	(0.3400)		(0.0561)
BUYNO	-1.8874***	BUYNO	2.6069***
	(0.1079)		(0.1086)
PRICE	-0.1623***		
	(0.0060)		

Demographic Interactions

NONGMO* AGE	-0.0013	NANOAG* AGE	-0.0014	NANOPACK* AGE	0.0007	NANODROPS* AGE	-0.0090***
	(0.0027)		(0.0031)		(0.0026)		(0.0028)
NONGMO* HHSIZE	0.0617	NANOAG* HHSIZE	-0.0529	NANOPACK* HHSIZE	-0.0237	NANODROPS* HHSIZE	-0.0040
	(0.0412)		(0.0452)		(0.0373)		(0.0404)
NONGMO* COMM	-0.0007	NANOAG* COMM	0.0595	NANOPACK* COMM	0.1117	NANODROPS* COMM	0.1841*
	(0.0956)		(0.1074)		(0.0887)		(0.0961)

Table 5.6 (con't)

NONGMO* INCM	-0.0011	NANOAG* INCM	0.0040	NANOPACK* INCM	0.0132	NANODROPS* INCM	0.0045
	(0.0105)		(0.0117)		(0.0098)		(0.0105)
NONGMO* EDUYEAR	-0.0089	NANOAG* EDUYEAR	-0.0221	NANOPACK * EDUYEAR	-0.0190	NANODROPS* EDUYEAR	-0.0308*
	(0.0165)		(0.0180)		(0.0149)		(0.0161)
NONGMO* CHILD	-0.1133**	NANOAG* CHILD	0.0863	NANOPACK * CHILD	-0.0091	NANODROPS* CHILD	0.0341
	(0.0580)		(0.0642)		(0.0530)		(0.0573)
NONGMO* MARRIED	0.0101	NANOAG * MARRIED	0.0105	NANOPACK * MARRIED	0.0134	NANODROPS* MARRIED	0.0426
	(0.0966)		(0.1069)		(0.0886)		(0.0954)
NONGMO* MALE	0.1278	NANOAG* MALE	0.0457	NANOPACK * MALE	-0.0446	NANODROPS* MALE	-0.1350*
	(0.0837)		(0.0923)		(0.0764)		(0.0823)
NONGMO* READLABELS	0.0879*	NANOAG * READLABELS	-0.0290	NANOPACK * READLABELS	-0.0404	NANODROPS* READLABELS	0.0225
	(0.0513)		(0.0576)		(0.0478)		(0.0512)
NONGMO* MEMBER	0.3106**	NANOAG * MEMBER	-0.0539	NANOPACK * MEMBER	-0.1587	NANODROPS* MEMBER	-0.0699
	(0.1597)		(0.1776)		(0.1480)		(0.1584)
NONGMO* EMPL	0.1447	NANOAG* EMPL	0.1458	NANOPACK* EMPL	0.0775	NANODROPS* EMPL	-0.1968**
	(0.0914)		(0.1012)		(0.0834)		(0.0902)

Table 5.6 (con't)

NONGMO* INCM	-0.0011	NANOAG* INCM	0.0040	NANOPACK* INCM	0.0132	NANODROPS* INCM	0.0045
	(0.0105)		(0.0117)		(0.0098)		(0.0105)
NONGMO* EDUYEAR	-0.0089	NANOAG* EDUYEAR	-0.0221	NANOPACK * EDUYEAR	-0.0190	NANODROPS* EDUYEAR	-0.0308*
	(0.0165)		(0.0180)		(0.0149)		(0.0161)
NONGMO* CHILD	-0.1133**	NANOAG* CHILD	0.0863	NANOPACK * CHILD	-0.0091	NANODROPS* CHILD	0.0341
	(0.0580)		(0.0642)		(0.0530)		(0.0573)
NONGMO* MARRIED	0.0101	NANOAG * MARRIED	0.0105	NANOPACK * MARRIED	0.0134	NANODROPS* MARRIED	0.0426
	(0.0966)		(0.1069)		(0.0886)		(0.0954)
NONGMO* MALE	0.1278	NANOAG* MALE	0.0457	NANOPACK * MALE	-0.0446	NANODROPS* MALE	-0.1350*
	(0.0837)		(0.0923)		(0.0764)		(0.0823)
NONGMO* READLABELS	0.0879*	NANOAG * READLABELS	-0.0290	NANOPACK * READLABELS	-0.0404	NANODROPS* READLABELS	0.0225
	(0.0513)		(0.0576)		(0.0478)		(0.0512)
NONGMO* MEMBER	0.3106**	NANOAG * MEMBER	-0.0539	NANOPACK * MEMBER	-0.1587	NANODROPS* MEMBER	-0.0699
	(0.1597)		(0.1776)		(0.1480)		(0.1584)
NONGMO* EMPL	0.1447	NANOAG* EMPL	0.1458	NANOPACK* EMPL	0.0775	NANODROPS* EMPL	-0.1968**
	(0.0914)		(0.1012)		(0.0834)		(0.0902)

The optimistic consumers were significantly different from the pessimistic consumers especially for nanotechnologies. Optimistic was redefined here when consumer rated 5 for OPT[2] (optimistic), 3 for UN (uncomfortable), 1 for SUS (suspicious) and 5 for both HH (the humanhealth category) and EN (the environmental category), indicating that the consumers were always optimistic with new food technology, not at all suspicious about food items even of some food safety incidents. They also believed that specific new technology (genetically modification, different nanotechnologies) might bring much more benefits than risks to both human health and the environment. Thus, the optimistic consumers were more likely to pay for canola oil product: $6.70 more if nanotechnology was applied to canola seed production; $2.08 more if the oil was packaged in a nanotech advanced bottle; and $5.29 more if nanodrops were added to bring health benefits.

Table 5.7 Total Willingness-to-pay Estimates Based on the Full Model

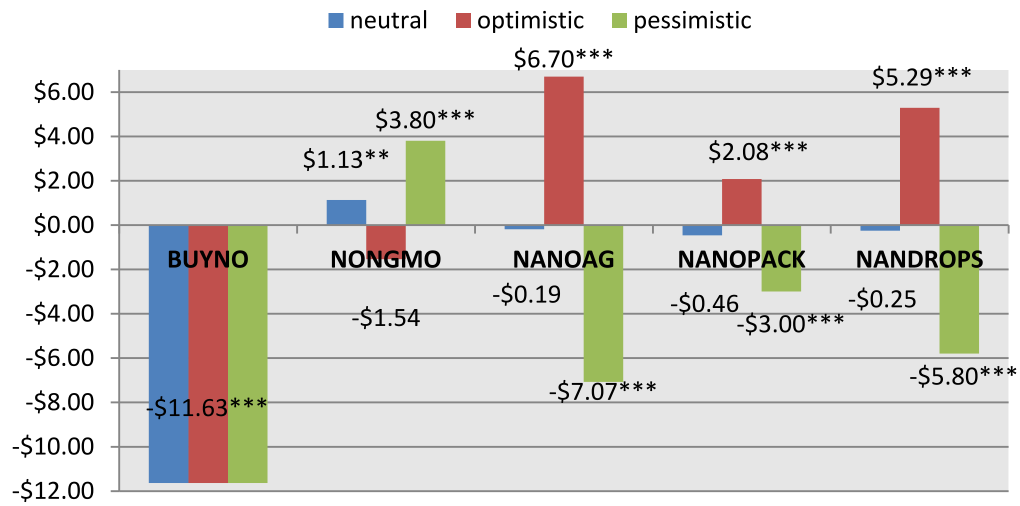
$\overline{D}$(Average Demographic Values) : AGE=40.8; HHSIZE=3; COMM=1; INCOM=6.5($65000); EDUYEAR=15; CHILD=1; MARRIED=1; MALE=1; READLABELS=3; MEMBER=0; EMPL=1;

	Optimistic *OPT=5,UN=3,SUS=1, HH=5,EN=5*		**Neutral** *All values equal 3*		**Pessimistic** *OPT=1,UN=3,SUS=5, HH=1,EN=1*	
	WTP	P value	WTP	P value	WTP	P value
BUYNO	-$11.63*** ($0.63)	0.00	-$11.63*** ($0.63)	0.00	-$11.63*** ($0.63)	0.00
NONGMO	-$1.54 ($1.01)	0.13	$1.13** ($0.53)	0.03	$3.80*** ($1.03)	0.00
NANOAG	$6.70*** ($1.18)	0.00	-$0.19 ($0.59)	0.75	-$7.07*** ($1.21)	0.00
NANOPACK	$2.08*** ($0.97)	0.03	-$0.46 ($0.49)	0.35	-$3.00*** ($0.99)	0.00
NANDROPS	$5.29*** ($1.05)	0.00	-$0.25 ($0.52)	0.63	-$5.80*** ($1.06)	0.00

Note: ***,**,* indicate significant at the 1%, 5%, and 10% significance levels respectively. Standard Error are in parentheses.

[2] The abbreviations refer to Table 5.2.

Figure 5.5 Total Willingness-to-pay Estimates Based on the Full Model



Note: ***,**,* indicate significant at the 1%, 5%, and 10% significance levels respectively. Standard Error are in parentheses.

5.5. Results and Conclusion

We investigated the underlying reasons for heterogeneous preference and willingness-to-pay (WTP) for new food technologies, including genetically modification, nanotechnology used in food production and cultivation, used in food package area and in the final food product. To reach this goal, consumers' WTP for attributes presented by different food technology were linked with socio- demographic and psychological information. In the context of socio-psychological determinants, perceived risk and benefits associated with new food technologies were used in this study in Likert scale questions. Mixed logit models were used to analyze data from choice experiments.

Results showed no significant difference across consumers regarding genetically modification technology (GMO) applied to food associated with different demographic backgrounds, except for a few factors. For example, families with more children were found to buy non-GMO canola oil less likely. It was found that consumers who paid attention to product labeling and/or affiliated to environmental friendly association were more likely to choose non-GMO canola oil.

Other prominent determinants affecting consumer preference for nanotechnologies were consumers' age, household annual income, and employment status as well as living locations. For instance, senior consumers were less likely to buy canola oil produced from canola seed if nanotechnology was applied or nanotech advanced nanodrops were added. However, no significance was found for product if they were packaged in nanotechnology applied bottles. In addition, people who lived in city or suburb area were more likely to accept food nanotechnology compared to other areas.

Although interpretation is feasible in a mixed logit model, we presented the results in the more meaningful form of marginal willingness-to-pay: individual WTP and total WTP. Individual WTP referred to interaction between technology attribute variables and the determinant variables. This helps for designing niche markets and pertinent policy mechanism. Furthermore, in our results, perceived risk and benefit portrayed significant heterogeneity across respondents, especially when respondents were presented with questions about specific technologies instead of when given in general terms. By identifying consumers as optimistic, neutral and pessimistic, we found that optimistic consumers were more likely to acceptance nanotechnology and pay a premium for product if such technology applied. And pessimistic consumers were less likely to buy these products or paying less.

The full model with all interactions included yielded results consistent with the previous one. Therefore, total WTP were calculated based on the full mixed logit model results. In a nutshell, consumers preferred non-GMO products on average. There are still potential opportunities for nanotechnologies and related applications in food, as optimistic consumers were willing to pay more and neutral consumers, where the majority consumers can be classified, showed no significant dislike so far.

5.6. Discussion and Implications

Using a conjoint stated choice survey and mixed logit model, this analysis assessed the impacts of individual differences consumer placed on food nanotechnologies. Both producers and marketers should note that consumers may be willing to pay a significant amount for some attributes of their products, attributes which are often not related to product itself. Characteristic differences including age, income, employment and living community may affect consumers' purchase decision. This helps marketers to locate niche markets and to design fit strategies to increase profit through consumer segments.

Perception and attitude analysis offers a different perspective in understanding consumer preference in nanotechnology in the food system as compared to past social science studies. The results indicate consumers' subjective views play an important role in their decision makings. This is equally true when new food technologies are involved. However, it is a double-edged sword for consumers. On one hand, consumers may be easily satisfied with their purchase following their wills. On the other hand, consumers may be vulnerable to their wrong perception due to knowledge deficit or other similar factors. Thus, it is responsible for scientists, producers and policy regulators to better educate the consumers through several schemes, such as publishing more relevant scientific results, providing detailed labels and description on the product and designing stricter regulations for products before they are commercialized.

Chapter 6 Conclusion and Further Research

6.1. Summary

This study analyzed new food technologies and related applications in food, especially with respect to nanotechnology. Questions and doubts were raised about public support, market potential and regulation of food nanotechnology. The questions were approached from the viewpoint of consumers. With an application of stated preference data, we scrutinized consumers' benefit and risk perceptions for new attributes developed through nanotechnology. In addition, consumer preference for food nanotechnology was gauged in terms of estimating willingness-to-pay using choice models.

Although they are in the early stage of the development, nanotechnologies are expected to bring many advances to food products. However, these advances are accompanied by uncertainties and even potential harm. In addition to published scientific research, public inclination might also change the growing path of a new technology. The majority of the public had neural attitudes toward most new food technologies, which would offer an opportunity for further introduction of nanotechnologies. Optimistic and pessimistic consumers, classified by their perceptions about new food technology, showed distinct preference. Besides evaluating the dollar value consumers placed on different food nanotechnologies, we sought to explain willingness-to-pay through their perceived benefits and perceived risks associated with nanotechnologies. This allowed us to better understand the connection between consumer food safety concerns and new attributes associated with nanotechnologies.

Chapter 2 introduced the national online survey used in this study. The survey was designed to cover questions raised in previous literature. The major contribution of this empirical analysis is not only to add to the limited literature about the gap between nanotechnology and society, but also is the very first to quantify consumer preference on a real product featuring different nanotechnology applications. The target product chosen in this study is canola oil. Canola oil is widely used and has some nanotech features already been commercialized. Choice experiment was applied through in the survey. A profile of new food technology attributes with three specific nanotechnologies was aligned with price attributes. This led to the elicitation of consumer willingness-to-pay for attributes while considering different covariates such as consumer risk perceptions and attitudes.

Chapter 3 generally reviewed the background and framework of our methodology. Subsequently, chapter 4 and 5 derived the empirical models. In chapter 4, consumer preference were investigated with a conditional logit model (CL) and a mixed logit model (ML). Results from the CL model presented significant coefficients for all new technology attributes, except for nanopack. Consistent WTP results showed that: on average, consumers might pay $1.06 more for non-genetically modified canola oil (a 48 fl. oz. bottle); $0.52 less for the product if canola seed was produced with nanotechnology during cultivation; and $0.52 more if nanodrops were added to the final product which was designed to bring health benefit. However, no difference was found for a bottle of canola oil if nanotechnology was applied to create the bottle, when comparing to a typical product which could be found in retail stores and mostly genetically modified.

Results from the ML model relate to the CL model provided some different results regarding both significance and signs of the coefficients of attribute. The ML model also indicated considerable unobserved heterogeneity across individuals. Fitness criteria implied improvement of model fit when shifting from conditional logit to mixed logit model. The WTP estimates suggested that: consumers still would pay more for non-genetically modified canola oil $0.99 per bottle (e.g. 48 fl. oz.), but pay less for nanoagriculture featured product about $0.95 per bottle. In contrast, consumers would pay less for a product if it was packaged in a nanotech advanced bottle. No significance was revealed for the nanodrop feature in coefficient estimates, but strongly significant standard deviation were found for the coefficient. This suggested consumers' heterogeneous taste toward nanotechnologies. Results from this model might also allow dividing consumers by positive and negative intention, which helps better understanding of data.

Chapter 5 focused on the underlying reasons of consumers' heterogeneous preference for nanotechnologies. The mixed logit model in this chapter allowed for interactions between attribute variables with consumer characteristics, including demographic and perception variables, to capture the unobservable variation in consumer taste to increase the fit of the choice model. Several determining factors were found that affected consumers' buying behavior. For example, the more children in the family, the less likely the household might choose non-genetically modified products which are typically more expensive than regular products. On the other hand, the more frequently one paid attention to the labels, the more likely the customer would choose non-GMO. For nanotechnologies, the prominent determinants were age, household annual income and employment status as well as living location. For instance, seniors were less likely to buy canola oil products if they were produced from canola seed with nanotechnology, or if they were packed in nanotech advanced bottles. Additionally, city or suburban residents were more open to accept food nanotechnology.

Beyond socio-economic factors, the interaction effects of consumer socio-psychological values were also examined. The survey asked about consumers' benefit and risk perceptions for new food technology in general and in specific spelling-out terms. We found that concerns about new food technology significantly increased if the technology was explicitly specified in contrast to being muggled as generic. Therefore, we derived WTP based on results from the full mixed logit model combining all possible interactions as discussed. We reiterated preference for non-GMO was positive as before for majority except consumers who were strongly optimistic about the genetically modification. That is, consumers who were neutral about GM might on average pay \$1.13 more for a bottle of non-GMO canola oil and pessimistic consumers (about GM) might pay \$3.80 more for non-GMO. In the context of nanotechnologies, significant and disrupt preference were observed amongst consumers if they identified themselves as optimistic, neutral and pessimistic. Specifically, consumers who were highly positive with new food technology would like to pay \$6.70 more for a bottle of canola oil if it was produced with nanoagriculture; \$2.08 more if it was packed in nanotech advanced bottle; and \$5.29 more if nanodrops were added to the oil. However, pessimistic consumers were in the opposite side: they might pay $7.07 less for the feature of nanoagriculture; $3.00 less for the feature of nanopackage; and $5.80 less for nanodrops. Results from this study would help marketers locate niche markets through careful examination of consumers' individual difference.

Additionally, consumers' perceptions of nanotechnology were analyzed throughout the survey and the choice study. This contributes to filling the gap between social science research and technology development progress in the literature. This would help the food industry marketers and policy makers grasp a better understanding of the public choice when introducing nanotechnology into the food system. As implied in the results, consumers appeared to be informed about the new technology. Their choices of nano products were significantly increased when the names of technologies were spelled out. In order to designed proper policy and regulations, more work needs to be done to identify different branches of nanotechnology, and their impact to consumers. Moreover, experience and lessons from genetically modification in the last decade would also apply for the new nanotechnology in a large extent.

6.2. Expectation of Future Research

The analyses showed that benefit and risk perception have differential impacts on consumer preference for nanotechnologies. Consumers were willing to pay a premium for products enhanced by nanotechnology. Further, perceptional values significantly affected the extent of WTP. The results from this study could serve as a launching pad for future related research, as explained before. Application of experimental auction, field experiment, or revealed preference data if accessible could enhance the realism of the analyses in this study. Larger context of socio-psychological studies of benefit and risk perception would also better to discern consumer heterogeneous preference, in an especial respect to nanotechnology and any other new food technologies. While the results showed that the spelling out effect did affect preference, more factors as information, confidence, trust values could be tailored in future study for nanotechnology. One may argue that factors not included in this study could cause omitted variable bias. The future solution to this issue is to increase the data coverage and question length, so that analysis of such relevant variable is feasible and effective. More advance modeling, such as discrete model in the WTP space could be utilized to address better in heterogeneity research (Hole and Kolstad, 2012).

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Appendix

Converted survey questionnaire from online version

UNIVERSITY OF KENTUCKY

College of Agriculture

Welcome!

Thanks for taking part in this research!

This study is conducted by:
Department of Agricultural Economics at the University of Kentucky.

We are interested in your choices of canola oil that you may typically buy at the grocery store. By "canola oil" we mean the oil that is purchased for cooking purpose. **We greatly appreciate your answers to this survey as they will help us better understand several very important issues facing American consumers' preferences for canola oil**.

As you go through the survey, please take time to complete all parts of the survey. If you have any questions, please feel free to contact us by the contact information in the end of the survey.

Let's get started:

***Did your household ever purchase canola oil in the past year?**

- ◯ Yes
- ◯ No
- ◯ Never buy canola oil

Part I.

***How much do you usually spend on canola oil products in a typical year?**

- ◯ $0~$4
- ◯ $5~$9
- ◯ $10~$19
- ◯ $20~$29
- ◯ $30 or more
- ◯ I don't know

What product features do you usually look for when buying canola oil? Assume that the oil you buy is fresh and well presented (i.e., no damaged packing, etc.)

***I usually buy...**

- ◯ National Brand
- ◯ Store Brand

***The container of canola oil I usually buy is:**

- ◯ Opaque Container
- ◯ Clear Container

***The size of the container I usually buy is:**

- ◯ Small (<16 fl. oz.)
- ◯ Medium (24~48 fl. oz.)
- ◯ Large (> 48 fl. oz.)

***The price I usually pay for a bottle of canola oil is: (assume 1 bottle = 48 fl.oz.)**

- ◯ $2~$2.99
- ◯ $3~$3.99
- ◯ $4 $4.99
- ◯ $5~$5.99
- ◯ $6~$6.99
- ◯ $7~$7.99
- ◯ $8~$8.99
- ◯ $9~$9.99
- ◯ $10 and above

***The canola oil I usually buy is:**

- ◯ Domestic (USA)
- ◯ Imported from Canada
- ◯ Imported from other countries besides Canada
- ◯ I don't know

***And, I usually buy:**

- ◯ Organic canola oil
- ◯ Non organic canola oil
- ◯ I don't know

For the following question, even if you are not sure of the answer, we are interested in your perceptions of the canola oil you most often buy.

***Based on what you know or what you think, is the canola oil you most often buy ...(check ALL that apply)**

◯ Low in saturated fat

◯ Organic

◯ Free of genetically modified/engineered ingredients

◯ Free of pesticide residues

***How important are the following canola oil features to you when you choose to buy in the grocery store?**

	Very Important	**Somewhat Important**	**Not Very Important**	**Not At All Important**	**Don't Know No Response**
Brand					
Type of Container					
Size of Container					
Price					
Country Origin					
Organic					
Nutrient					

Part II.
***Regardless whether you have purchased canola oil in the past year.**

Suppose you have to choose food products produced with new technology. Which statement will be the BEST to describe your feeling?

	Strongly Disagree	Slightly Disagree	Neither Disagree Nor Agree	Slightly Agree	Stongly Agree
I am optimistic about new technology applied in food products.					
I feel uncomfortable regarding new food technology.					
As a result of food safety incidents, I am suspicious about the safety of certain food products.					

Modern agricultural technology enables a variety of ways to produce and prepare food. We are interested in knowing how you the relative benefits and risks of different types of technologies given below, in respect to Human Health and the Environment.

***Please indicate in each category below the impact of different technologies on <u>Human Health</u>.**

	Risks much greater than Benefits	Risks slightly greater than Benefits	Risks = Benefits	Risks slightly greater than Benefits	Risks much greater than Benefits
Use of hormones in food producing animals					
Use of antibiotics in food producing animals					
Use of food additives					
Use of irradiation					
Use of genetically modified or engineered crops to increase crop production					
Use of cloning in food production					
Use of nanotechnology in food production/cultivation					
Use of nanotechnology in food packaging					
Use of nanotechnology to change properties of final food products ☐					

***Please indicate in each category below the impact of different technologies on Environment.**

	Risks much greater than Benefits	Risks slightly greater than Benefits	Risks = Benefits	Risks slightly greater than Benefits	Risks much greater than Benefits
Use of hormones in food producing animals					
Use of antibiotics in food producing animals					
Use of food additives					
Use of irradiation					
Use of genetically modified or engineered crops to increase crop production					
Use of cloning in food production					
Use of nanotechnology in food production/cultivation					
Use of nanotechnology in food packaging					
Use of nanotechnology to change properties of final food products ☐					

Part III. Please carefully read the instructions before proceeding.

In this part you will be presented with purchase situations for canola oil. For each situation, please imagine you are planning to purchase canola oil. You will have a number of different options described by a set of different features. You will be asked to indicate your preferred choice in each situation and then choose among option A, B or C.

When making your choices, please note the following:

- **Please choose ONLY ONE OPTION in each choice situation**
- **Assume that the options in one situation are the ONLY ones available**
- **DO NOT compare options in different situations**

You may encounter a few options that seem counter intuitive (e.g., a lower price but a higher number of features). Be assured that this is not an error but part of the design of the survey. Simply choose the one canola oil option that you prefer the most based on its characteristics.

*Example

Definition of Feature 1 | **Definition of Feature 2** | **Definition of Feature 3**

Features	Option A	Option B	Option C
Feature 1		✓	I would not purchase any of these products
Feature 2	✓		
Feature 3	✓		
Feature 4			
Price ($ /48fl.oz.)	$5.99	$11.99	

I would choose option:

- ○ A
- ☑ B
- ○ C

One technology that may be adopted by the canola oil industry is called **Nanotechnology**. Nanotechnology involves research and technology development at the atomic, molecular, or macromolecular levels in the dimension scale of approximately 1 100 nanometers range to create and use structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size.

A nanometer is one billionth of a meter or one eighty thousandths of the width of an average human hair. Nanotechnology has begun to find applications in food.

Three types of nanotechnology may be relevant to canola oil production:
(A) Canola seeds might be produced under nanomonitoring in that water, fertilizer, or pesticide may be applied more efficiently and therefore reduces production cost and improve environmental quality. We refer to this technology as **NanoAgriculture**.

(B) Canola oil bottle may be produced through nanotechnology to keep canola oil fresh for a longer period of time and to alert consumers if the quality of oil starts to deteriorate. We refer to this technology as **NanoPackaging**.

(C) Nanodrops may be added to canola oil to block cholesterol from being absorbed by human digestive system. We refer to this technology as **NanoDrops**.

Now suppose you are shopping for canola oil products. The following choices are the ONLY ONES available to you in the grocery store.

Again, the canola oil you buy is fresh and well presented (i.e., no damaged packaging etc.) Please examine each choice below, **keeping in mind that, in a real life situation**, you are paying for the product that you choose. Please choose **ONE and ONLY ONE of Option A, B or C**, and mark the choice **that closely reflects your real decision.**

All products are in standard packages of 48 fl. oz. (fluid ounces) per bottle (about 1.5 pounds).

For comparison purpose:
* Currently canola oil on the U.S. market is mostly GM canola oil and is priced between $3~$4 per 48 fl. oz.
* Organic canola oil or canola oil labeled as “non GM” is usually priced between $5.52~$14.02 per 48 fl.oz.

NanoAgriculture
Canola seeds produced under nanomonitoring to use water, fertilizer, or pesticide more efficiently to reduce cost and improve environmental quality

NanoPackaging
Nanotechnology bottle to keep canola oil fresher for longer; or to alert consumers if product starts to deteriorate

NanoDrop
Intentionally added nano drops carrying phytosterols to block cholesterol from being absorbed by human digestive system

C1. Consider the following choice situation.

Features	Option A	Option B	Option C
NanoAgriculture	✓		I would not purchase any of these products
NanoPackaging			
NanoDrops	✓		
Non-GMO		✓	
Price ($/48 fl.oz.)	$5.99	$11.99	

I would choose option:

- ◯ A
- ◯ B
- ◯ C

Please do not compare across situations

C2. Consider the following choice situation:

Features	Option A	Option B	Option C
NanoAgriculture		✓	I would not purchase any of these products
NanoPackaging			
NanoDrops	✓		
Non-GMO	✓		
Price ($/48 fl.oz.)	$2.99	$8.99	

I would choose option:

- ◯ A
- ◯ B
- ◯ C

NanoAgriculture
Canola seeds produced under nanomonitoring to use water, fertilizer, or pesticide more efficiently to reduce cost and improve environmental quality

NanoPackaging
Nanotechnology bottle to keep canola oil fresher for longer; or to alert consumers if product starts to deteriorate

NanoDrop
Intentionally added nano drops carrying phytosterols to block cholesterol from being absorbed by human digestive system

C3. Consider the following choice situation:

Features	Option A	Option B	Option C
NanoAgriculture	✓		I would not purchase any of these products
NanoPackaging	✓	✓	
NanoDrops	✓		
Non-GMO	✓		
Price ($/48 fl.oz.)	$8.99	$2.99	

I would choose option:

- ◯ A
- ◯ B
- ◯ C

Please do not compare across situations

C4. Consider the following choice situation:

Features	Option A	Option B	Option C
NanoAgriculture		✓	I would not purchase any of these products
NanoPackaging		✓	
NanoDrops		✓	
Non-GMO	✓	✓	
Price ($/48 fl.oz.)	$5.99	$8.99	

I would choose option:

- ◯ A
- ◯ B
- ◯ C

NanoAgriculture
Canola seeds produced under nanomonitoring to use water, fertilizer, or pesticide more efficiently to reduce cost and improve environmental quality

NanoPackaging
Nanotechnology bottle to keep canola oil fresher for longer; or to alert consumers if product starts to deteriorate

NanoDrop
Intentionally added nano drops carrying phytosterols to block cholesterol from being absorbed by human digestive system

C5. Consider the following choice situation:

Features	Option A	Option B	Option C
NanoAgriculture	✓	✓	I would not purchase any of these products
NanoPackaging		✓	
NanoDrops	✓		
Non-GMO		✓	
Price ($/48 fl.oz.)	$11.99	$5.99	

I would choose option:

- ◯ A
- ◯ B
- ◯ C

Please do not compare across situations

C6. Consider the following choice situation:

Features	Option A	Option B	Option C
NanoAgriculture	✓		I would not purchase any of these products
NanoPackaging	✓		
NanoDrops		✓	
Non-GMO	✓	✓	
Price ($/48 fl.oz.)	$5.99	$2.99	

I would choose option:

- ◯ A
- ◯ B
- ◯ C

NanoAgriculture
Canola seeds produced under nanomonitoring to use water, fertilizer, or pesticide more efficiently to reduce cost and improve environmental quality

NanoPackaging
Nanotechnology bottle to keep canola oil fresher for longer; or to alert consumers if product starts to deteriorate

NanoDrop
Intentionally added nano drops carrying phytosterols to block cholesterol from being absorbed by human digestive system

C7. Consider the following choice situation.

Features	Option A	Option B	Option C
NanoAgriculture			I would not purchase any of these products
NanoPackaging	✓		
NanoDrops		✓	
Non-GMO		✓	
Price ($/48 fl.oz.)	$2.99	$8.99	

I would choose option:

- ◯ A
- ◯ B
- ◯ C

Please do not compare across situations

C8. Consider the following choice situation:

Features	Option A	Option B	Option C
NanoAgriculture		✓	I would not purchase any of these products
NanoPackaging	✓	✓	
NanoDrops	✓		
Non-GMO		✓	
Price ($/48 fl.oz.)	$5.99	$11.99	

I would choose option:

- ◯ A
- ◯ B
- ◯ C

Part IV.
As you may probably feel now, one of our interests is to understand what you know about nanotechnology and its applications in the food we consume. We will ask you several questions about the technology.

This is not a test. Guessing is certainly OK.

***For each of the following statement please indicate whether you believe the statement is:"True", "False", "DK/NS" (Don't Know or Not Sure).**

	True	False	DK/NS
By Eating nanofoods, a person's genes may also become modified			
Nanofoods are currently being sold in the U.S.			
U.S. food regulations require the labeling of food items which may contain nanoparticles			
We unknowingly intake naturally occurred nanoparticles			
In the U.S., nanotechnology has just been applied in food production for the past 3 years			

***How well informed would you say you are about nanofoods? Would you say...?**
- ☐ Very well informed
- ☐ Somewhat informed
- ☐ Not Very informed
- ☐ Not at all informed
- ☐ Don't Know

***Compared to nanofood, how well informed would you say you are about genetically modified food? Would you say...?**
- ☐ Very well informed
- ☐ Somewhat informed
- ☐ Not Very informed
- ☐ Not at all informed
- ☐ Don't Know

***At which level will you agree or disagree:**

	Strongly Disagree	Slightly Disagree	Neither Disagree Nor Agree	Slightly Agree	Stongly Agree
When eating nanofoods, I am exposed to risks.					
I gain many benefits if I consumed nano based food or food related products.					
I am willing to accept the risk of nanofoods.					
I would like to reap the benefits of consuming nano related food products.					

***Suppose you want to find out more about nanofoods. Please indicate how much would you trust the sources in the following table.**

	Very Trustworthy	Somewhat Trustworthy	Not Very Trustworthy	Not At All Trustworthy	I Don't Know
The US government					
The food industry					
farmers' association					
family/friends					
research institutions (e.g. universities)					
consumer associations					

The following statements concern your opinion regarding the regulation of nanofoods:e.g. labeling requirement. Please indicate your level of agreement or disagreement.

Mandatory labeling requires all producers to clearly and prominently label any product that are made from nanotechnology. Under a voluntary labeling scheme, producers can choose to label or not to label products that are made from nanotechnology as long as the information they provided is truthful and not misleading.

***Please indicate your opinion level about the following statements:**

	Strongly Disagree	Slightly Disagree	Slightly Agree	Stongly Agree
The public is sufficiently involved in the regulation of nanofoods				
Even if food prices were higher, the consumers' 'right to know' warrants a mandatory labeling of nanofoods				
The decision about introduction of nanofoods to the U.S. should be left to experts				
There is no need for mandatory labeling of nanofoods if the final product quality is the same				
Voluntary labeling might be used as a marketing tool rather than providing useful consumer information				
Stricter regulations for approving nanofoods are better than a mandatory labeling system for nanofoods				
Overall mandatory labeling is preferable to voluntary labeling				

We would also like to get your opinions on the following statements referring to nanotechnology in general and NOT ONLY those used in agricultural and food production. Please read carefully and indicate your agreement or disagreement.

	Strongly Disagree	Slightly Disagree	Neither Disagree Nor Agree	Slightly Agree	Stongly Agree
***Ethical Issues**					
The benefit of developing nanotechnology far outweighs the potential for abuse.					
Research in areas like nanotechnology is making us less human.					
Corporations will benefit from things like nanotechnology, but individual human beings will find their life worsened.					
The application of nanotechnology may help third world countries with food and clean water.					
***Social Issues**					
Nanotechnology can improve the quality of life of human beings.					
We do not have the social maturity to deal with the possible conflicts that may arise from nanotechnology.					
***Economic Issues**					
If nanotechnology is economical, it could be of great value.					
A large investment in nanotechnology is unlikely to justify its commercialization in any time soon.					
The society is investing too much money and resource into nanotechnology, which could have been used to help our current economy.					
***Environment Issues**					
Without nanotechnology, we would eventually still be able to mitigate the problems that industrial society has wrought on the environment.					
Nanoparticles will be distributed into the environment which would have unknown toxicity and might threaten the nature.					
Nanotechnology can help reduce our dependence on consuming the world's resources.					
***Human Health Issues**					
Nanotechnology will improve food packaging and storage techniques which will make food safer.					
Nanotechnology will make food more nutritious.					
Some currently unknown properties of nanotechnology may harm human health through food intake.					

Part VI.

***Are you...**

Female

Male

***What's your age?**

***What is your marriage status?**

Never Married

Married

Living Together but not Married

Divorced

Widowed

***How many people, including yourself, living in your household? (put a number here, e.g.3)**

***If you have children live in your household, how many of them fall into each of the following age group? (if no, put 0 in each box)**

1~4 years old

5~11 years old

12~17 years old

***What is the highest level of education that you have completed?**

- ☐ Never attended school
- ☐ Grade School (grades 1 to 9)
- ☐ Some High School
- ☐ High School Graduate
- ☐ Post secondary trade or technical School Certificates/Degree
- ☐ Some University Or College
- ☐ College Diploma/Degree
- ☐ University undergraduate Degree
- ☐ Some Post Graduate University Study
- ☐ Post Graduate Degree (e.g. masters or PhD, or other professional degrees)
- ☐ Declined to Respond

***What is your employment status?**

- ☐ Working Full or Part Time
- ☐ Full or Part Time Student
- ☐ Unpaid Work from Home or Homemaker
- ☐ Retired
- ☐ Decline to Respond

***What is your total household income before taxes?**

***In which state do you current live**

***Please describe the community in which you currently live:**

☐ City
☐ Suburb
☐ Small Town
☐ Countryside or Rural Area

***Are you a member of or associated with any environmental group?**

☐ No
☐ Yes

Please explain

☐
☐

***Do you usually read the labels when you are buying food products?**

☐ Regularly
☐ Occasionally
☐ Rarely
☐ Never

Vita

Author's Name – Guzhen Zhou
Birthplace – Jiangxi, China
Birthdate – January 30, 1988

Education

Ph.D. in Agricultural Economics **08/2008–*05/2013***
Department of Agricultural Economics, University of Kentucky
Dissertation title: "Applications of Nanotechnology in the Food System: Consumer Acceptance and Willingness to Pay"

M.Sc. in Economics **2011**
Department of Economics, University of Kentucky, degree obtained in May 2011

B.Sc. in Economics **2004-2008**
Huazhong University of Science & Technology, Wuhan, China

Research interests

Marketing and Consumer Economics, Consumer Behavior, Marketing and Demand Analysis; Non-market Valuation, Discrete Choice Modeling, Experimental Economics.

Working Papers

Zhou, G.,W. Hu, and J. Schieffer. 2013. "Public Acceptance of and Willingness to Pay for Nanofood: Case of Canola Oil". Department of Agricultural Economics, University of Kentucky. Dissertation title: "Applications of Nanotechnology in the Food. (Chapter 4 in Dissertation)

Zhou, G., W. Hu, and M. Pan. 2012. "Consumer Demand and Preference for Eco-friendly Labeled Commercial Fish Commodities: An Application to Tuna Steak" Selected poster presented in Annual Meeting of AAEA, Seattle, WA, August 12-14.

Zhou, G., W. Hu, M. Batte, T. Woods, and S. Ernst. 2011 "Household Grocery Shopping Destination Allocation: Have Local Stores Caught on with the Rise of Local Foods?" Selected poster presented in annual meeting of AAEA, Pittsburgh, PA, July 24-26. (*submitted* to International Food and Agribusiness Management Review, **in 1st review**)

Zhou, G. and L. Maynard. 2010. "Willingness-to-Pay for New Products in a University Foodservice Setting" Selected paper, Annual Meeting of AAEA, Seattle, WA, August 12-14.

Zhou, G., W. Hu, M. Batte, T. Woods, and S. Ernst. 2, Denver, CO, July 25-27

Grant

Schieffer, J. (PI), **G. Zhou.** "National Survey on Public attitudes about nanotechnology applied in food and food related products", $2000, funded by the College of Agriculture, UK Research Activity Award, 08/2012.

Research and Work Experience

Graduate Research Assistant, University of Kentucky **2008 -2013**

8. **Dissertation Project** **09/2010-Present**
   - Designed and delivered a nationwide survey in November 2012;
   - Quantitative and qualitative analysis; conjoint analysis, discrete choice estimation.

7. **Independent Study Project IV**: **01/2012**
   "Eco-Friendly Labeling and Its Impact on Fishery"
   - Analyzed conjoint experiment and applied Mixed Logit model;
   - Manuscript writing, academic presentations.

6. **Independent Study Project III:** **01/2011 - 05/2012**
   "Grocery Store Specializing & Local Food"
   - Determined factors that affected residents' purchasing habits with econometric model: SUR model;
   - Presented at an academic conference.

5. **Independent Study Project II:** **06/2010- 12/2010**
   "Milk Input Price Risk Management**"**
   - Analyzed up-to-date milk input price in agricultural future market with SAS;
   - Adopted hedging approach to develop price forecast.
   - **Manuscript: Zhou, G.** and L. Maynard. 2010. "Case Study Analysis: Hedging with Milk Input Costs using Future for a Dairy Processor". Department of Agricultural Economics, University of Kentucky.

4. **Independent Study Project I:** **1/2010 -06/2010**
   "Agribusiness Firms Growth Performance**"**
   - **Manuscript: Zhou, G.** and A. Katchova. 2010. "Performance and business growth strategies for agribusiness firms: a quantile regression analysis." Department of Agricultural Economics, University of Kentucky.

3. **Consulting Project** **09/2009 - 01/2010**
   - First hands-on market research project and team work with diverse graduate students;
   - Developed strategies including purpose and scope for the dairy product company, that hoped to expand its university food service sales;
   - Created and conducted surveys with campus-wide with the class;
   - Applied multiple logistic, market analysis of consumer preference and brand

awareness;
- Continued further analysis and presented a paper at an academic conference.

2. **Beginning Farmer Descriptive Analysis** **07/2009**
   - Familiarized with US Census Data and USDA Database; learnt to write academic report.

1. **Data Analysis** **2008- 2009**
   - Data entry, data coding and basic data manipulations.

Professional Reviewer **09/2011**
Society of Consumer Psychology 2012 Conference Reviewer
Teaching Assistant
Advanced Marketing Analysis (Graduate Level Class) 09/2012 -12/2012
Workshop Series: LaTex (host) 09/2012
Stata and SAS Workshop 08/2011
Summer Math Camp Program 08/2009

Skills
Computer: SAS, Stata, Microsoft Office Software Suite, LaTex
Language: Chinese/Mandarin (native); English (proficient)

Awards
Travel Grant to AAEA Meetings in Seattle, WA. $400, Grad School Office, 2012.
Travel Grant to AAEA Meetings in Pittsburgh, PA. $400, Grad School Office, 2011
Young Professional and Grad Student Travel Grants to Denver, $290, AAEA, 2010
Travel Grant to AAEA Meeting in Denver, CO. $400, Graduate School Office, 2010
Research Assistantship, Department of Agricultural Economics. $12700, since 2008

Affiliation and Service
Professional Affiliation: AAEA, SAEA, FDRS.

Others:
Vice President /Public Director **Since 2011**
Chinese Student and Scholar Association, University of Kentucky
Graduate Student Senator, Student Government **05/2011-04/2012**
Internal Affair Department
International Student Representative/Vice President **2009-Present**
International Student Council, Office of International Affairs, Univ. of Kentucky
Member at Large, Graduate Student Organization **2009-2012**
Department of Agricultural Economics, University of Kentucky