Perceptions of Nanotechnology in Canada and South Korea

By

Soon-Hee OH

A thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

In partial fulfillment of the requirements for the degree of

Master of Environment

Department of Environment and Geography

University of Manitoba

Winnipeg, Manitoba, Canada

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION

Perceptions of Nanotechnology in Canada and South Korea

By

Soon-Hee OH

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

Of

Master of Environment

THESIS ABSTRACT

As an emerging technology, nanotechnology (NT) is making rapid progress with respect to its commercial production, distribution, and marketing. Although nanoproducts are widely available in both Canada and South Korea, few studies have adequately explored the social implications of this new technology in either country or between countries with distinct cultural and societal differences. The current study is the first to compare public and expert attitudes regarding nanotechnology between North America and Asia. The objective of this thesis was to better understand how expert and public attitudes differ regarding science and technology and the possible human health and environmental risks associated with nanotechnology and nanoproducts. To accomplish this, interviews were conducted with the general public, university students, and nanotechnology experts from November, 2007 to May, 2008 in Canada and Korea to gauge risk perceptions around NT.

Overall, most respondents from Canada and especially Korea (84% vs. 94%) had heard of NT, but relatively few (24% vs.16%) indicated they were knowledgeable of the technology. Yet the respondents, especially Koreans, were generally highly optimistic about the technology. Respondents were most excited about the potential of NT for improved human health, especially Canadians, followed by environmental benefits. Respondents from both countries sorted out into three groups: opponents that were highly critical of NT, proponents that were highly supportive, and a third group, conditional proponents that seemed to evaluate benefits against the potential risks before making any decision. Male public respondents from both countries were less likely to be critical than their female counterparts.

Of the 16 independent variables that shaped attitudes towards science and technology and implications for perceptions regarding NT, concerns of social impacts, the environment, human health, and public input and trust in scientists, science, and technology were very important. Expertise in NT, levels of formal education, academic specialization, gender, age, religion, marital status, and financial wellbeing were also meaningful.

Regarding perceptions of health and environmental risks associated with NT, almost half of the respondents from each country (49% in Canada vs. 47% in Korea) were at least somewhat worried about the risks associated with NT. Respondents were much more concerned about NT-associated risks to human health than the environment. Ways that these risk perceptions might be mitigated also varied, especially between the public and experts. Although many respondents indicated they were concerned about NT-associated risks, these ultimately ranked much lower than other identified risks that are known to threaten human health and the environment. Interviews with experts provided greater detail on their attitudes towards risks associated with nanotechnology and nanomaterials. The interviews further identified that any risks could be best addressed, in decreasing order of importance, by increases in research, regulation, and more effective communication with the public.

Of the 20 independent variables that played an important role in shaping attitudes regarding health and environmental risks associated with NT, six of them, such as trust in scientists, companies, technology, as well as increased public debate, accountability of nano-industries, and regulation were all highly significant for respondents who recognized the need to address the substantial health and environmental risks. Age,

marital status, financial wellbeing, gender, discipline, and religion were also all significant. However, it is also important to note that there seemed to be little overall awareness in either country as to how the public might become better informed and involved in NT decision-making.

ACKNOWLEDGEMENTS

I must first thank all respondents from Canada and South Korea that participated in this research, without their active contribution this thesis would not have been possibly published. I would like to thank my advisor, Dr. Stéphane McLachlan for his great advice and support throughout my project. I am incredibly grateful to my advisory committee, Dr. Michael D. Mehta and Dr. Mark Hanson for their valuable advice and kindest cooperation, which enriched the project.

Many others have contributed to my graduate work. My colleagues in the Environmental Conservation Lab have been amazing supporters of this project. Specific thanks to Alam for his help with data analysis and Alexis, Brad, Colin, Melisa, Paul, Soon-won, and Troy for sharing their work. Also deserving thanks are my research assistant, Sun-Hee Lee and those that were of great help when collecting the data, HoK-Won Kim from University of Toronto, Hong-Chual Kim from the Citizen's Movement for Environmental Justice, and Dr. Yang-Ki Cho from Chonnam National University.

Throughout my life and study, I have been truly grateful to my family and best friends who have strongly supported and encouraged me during every stage of my difficulties. Their endless belief and friendship have always been powerful and spiritual energy for me to work through the struggles and finally left me more strong, wise, and humble.

Funding provided by Social Science and Humanities Research Council (SSHRC), Canada has helped facilitate this research and resulted in the first study that systematically compares attitudes of nanotechnology between Canada and South Korea.

TABLE OF CONTENTS

CHAPTER 4: Health and Environmental Risk Perceptions of Nanotechnology and Nanoproducts

CHAPTER 5: FINAL DISCUSSION

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: General Introduction

1. BACKGROUND

Since the emergence of science and technology, people have been excited about the potential of each for humanity. The great potential for scientific and technological progress has culminated in biotechnology (BT), *nanotechnology* (NT) (See Appendix 1 for terminology), information technology (IT), each which has numerous economic, societal, human health, and environmental *benefits* and *risks* (Appendix 1). These advances have substantial implications for society and our way of life in the future.

Applications of nanotechnology have enormous promise and have significant potential to benefit society and the environment (Grove-White *et al.*, 2004). Proponents claim that rapid improvements in nanotechnology have already produced products that are better in quality, but there are growing concerns that these materials may have unintentional and adverse implications for human health and the environment (European Commission, 2004).

Since the 1990s, industrial manufacturers have become increasingly worried that they will face regulatory challenges that aim to safeguard humans and the environment. Enhanced quality and function of *nanomaterials* (Appendix 1) that have substantial implications for future technology are already being used in many products that are readily available to consumers, such as sunscreen, cosmetics, toothpaste, paper, plastics, pharmaceutical tablets, sporting goods, and electronics amongst others (Roszek, de Jong, and Geertsma, 2005). However, there currently is a distinct lack of nano-specific regulations, and those that are in place existed previously for ostensibly equivalent bulk material (Albrecht, Evans, and Raston, 2006; Bowman and Hodge, 2007). By examining

the existing and potential implications of these materials and associated products, this study will help raise awareness and facilitate wide ranging dialogue of the knowledge gaps and concerns in decision-making around this technology now and into the future.

2. RATIONALE

The potential health, social and even environmental benefits of nanotechnology are great. However, most of the risks associated with nanotechnology remain largely unknown and unaccounted for, and nanoproducts available to consumers in Canada and South Korea (Korea) remain effectively unregulated. Few studies adequately evaluate consumer concerns regarding environmental and human health risks of nanotechnology, much less contrasting these attitudes with those of experts and a wide variety of industry, government, environmental, and consumer stakeholders. In part, this is because the field is so broad and because there is such a great diversity of nanomaterials (Alper, 2006), because bulk materials, which can be strengthened using nanotubes, nanoparticles or nanofibres, are seen (at least by industry and governments) as substantially equivalent to bulk products, and because there has been inadequate funding for independent research regarding any risks.

In this study, I have compared *public* and *expert* (Appendix 1) perceptions of risks associated with nanotechnology, compared these between Canada and South Korea, and contrasted these to a wide diversity of associated environmental and health risks. Ultimately, these outcomes will be characterized and presented in ways that help identify gaps in knowledge and help better shape management and decision-making across government, industry, academia, and society as a whole. In order to effect positive change

through this research process, there is need for better *risk communication* (Appendix 1) between government, researchers, industry, and the general public in order to move forward towards a better understanding and management of these technologies.

3. HYPOTHESIS

We predicted that respondents from South Korea would be more supportive of nanotechnology in part because of their greater anticipated support of science and technology as a whole, and that experts would generally be more supportive of nanotechnology than the public. Finally, because of its greater immediate ramifications we had anticipated that human convenience would be identified as more important than either potential health or environmental benefits.

4. LIST OF OBJECTIVES

Objective one: To better understand public and experts attitudes to NT in Canada and South Korea (Chapter 3). In particular, I wanted to:

- Understand how these attitudes related to more general attitudes toward science and technology
- Compare attitudes toward nanotechnology between Canada and Korea
- Compare public and expert perceptions

Objective two: To better understand public and expert attitudes towards human health and environmental risks associated with nanotechnology and nanoproducts (Chapter 4). In particular, as it relates to NT, I wanted to:

- Characterize attitudes towards human health and environmental risks
- Contrast attitudes towards human health and environmental risks between Canada and Korea
- Compare public and expert perceptions of human health and environmental risks

CHAPTER 2: Literature Review

1. DEVELOPMENT OF NANOTECHNOLOGY

1.1. Definition of nanomaterials

Nanotechnology is multidisciplinary, conventionally involving the fields of chemistry, physics, biology, material science and engineering, and, in recent times toxicology, of nano-objects or nano-tools (Albrecht *et al.*, 2006; Grove-White *et al.*, 2004). Nano refers broadly to manufactured materials, devices, systems, and structures with nano-scale dimensions (Sharpe, 2006), usually ranging in size from 1 to 100 nanometres (U.S. Department of Energy, 2006; Kalaichelvan, 2008).

Issues of scale are important for understanding the effects of physical, biological, and chemical properties on nanomaterials because at atomic level, materials can have enhanced or different properties compared to the same material at larger scales (Roszek *et al.*, 2005). The main reasons for the effects of this change are an increased relative surface area and the dominance of quantum effects, as increases in surface area results in increased chemical reactivity (Sharpe, 2006; Thomas and Sayre, 2005). The materials are categorized as carbon and inorganic nanomaterials. Nano-structured bulk materials are also relevant, because physical interactions at the (nano-scale) interface between biological structures and materials are critical in shaping biological responses (Roszek *et al.*, 2005).

Engineered nanoparticles incorporate a wide range of substances, including elemental metals, inorganic substances like titanium dioxide (TiO2) and zinc oxide (ZnO), and carbon-based fullerenes and their derivatives and composites (Albrecht *et al.*, 2006). However, nanoscale compounds often do not behave in ways that are similar to

their larger counterparts, including inhalation, ingestion, and skin penetration, and risks will often be a specific product or application, or through occupational exposure to workers (Sharpe, 2006). Although some studies have anticipated there to unforeseen human health and environmental risks and called for a precautionary moratorium on nanotechnology (e.g. ETC Group, 2003; Royal Society, 2004; Swiss Re, 2004), others feel that specific assessments of potential *hazards* (Appendix 1), exposure, and likelihood of toxic effects is warranted (Tsuji *et al.*, 2006).

1.2. Possible Risks from Nanoparticles

The same properties that create much of the promise for nano-sized materials can sometimes also make them toxic to cells and organisms (Powell and Kanarek, 2006). The properties being exploited by this technology, such as high surface reactivity and the ability to cross cell membranes, may have negative implications for human health. Nanomaterials can thus enter the human body through several pathways whereas nanoparticles can also exist in air, water, and soil while in eh environment (Hannah and Thompson, 2008; Hoet *et al.*, 2004; Robichaud et al., 2005)

Possible Health Risks from Nanoparticles

Hoet and his colleagues (2004) stated that human skin, intestinal tracts, and lungs are always in direct contract with the environment and are therefore potentially exposed to nanoparticles, the latter two also allowing for passive and/or active transport of various substances including water, nutrients, or oxygen. More specifically, human contact with manufactured nanoproducts that use nanoparticles of titanium dioxide, zinc oxide, carbon, and other nanotubes can possibly cause damage to vital body organs and tissues

because the nanoparticles could compromise the integrity of the blood brain barrier, induce immunotoxicity and neurotoxicity, and contribute to the possibility of carcinogenesis. They can thus be inhaled with air, swallowed, and may possibly enter the body through skin exposure (Hannah and Thompson, 2008; Wilsdon, 2004). During transportation, and especially the fabrication and handling of semi-finished or end-products at production facilities, workers can also come into contact with nano-manufactured materials and their inherent risks. However, research and information regarding the relative health *risk assessment* (Appendix 1) of manufactured nanoparticles and nanomaterials is still lacking because of its infancy. Applications containing nano-scale additives are being used by industry in commercially available nanoproducts and promise numerous benefits, including improvements in tools, in products and services, in medical diagnosis and health treatments (such as pharmaceutical genomics, neuromorphic equipment, regenerative medicine), in biochips with complex functions, in multiscale molecular systems, and in energy sources and electronic products (such as electronic devices, software for multiscale simulations, processes, systems, and flight) (Bowman and Hodge, 2007; Roco, 2005). These applications are generating much interest by creating potential environmental benefits such as those that arise from more effective filter, energy, fuel, environmental monitoring, and environmentally sensitive manufacturing technologies (Hannah and Thompson, 2008) and from better packaging (Kuzma and VerHage, 2006; San-guansri and Augustin, 2006).

However, public concern and even resistance regarding potential risks have influenced acceptance of new technologies in the market-place, especially applications related to genetically modified food (Henson, 2007; Savadori *et al.*, 2004; Siegrist, 2008).

A great deal more information is needed to determine how nanoparticles interact with the human body, involving the co-operation of governments, industry, academia and the public at national and international levels of organization (Roco, 2004). Some of the identified potential health risks rising from greater exposure including inhalation of nanoparticles (Hoet *et al.*, 2004); particle absorption through the skin (Swiss Re, 2004); particle absorption via the alimentary canal (Thomas and Sayre, 2005); nanoparticles in the body, and interactions with biological processes (Balshaw *et al.*, 2005).

Potential Environmental Risks with Nanoparticles

Depending on manufacturing techniques and anticipating their wide scale distribution, nanoparticles can be released into the water or the air and ultimately contaminate the soil and groundwater (Hannah and Thompson, 2008; Wilson, 2004). At the nanoscale, physical, chemical, and biological properties of materials that are highly desirable for applications within the commercial, medical, and environmental sectors differ in important ways from the properties of individual atoms and molecules or bulk matter (Thomas *et al.*, 2006; Dreher, 2004). In the greater environment, nanoparticles are likely also mobile and can travel significant distances by air or water (Wilson, 2004).

Much of the manufacturing takes place in closed environments, sometimes in low-pressure chambers. But during transport from production facility to application site, some degree of handling cannot be avoided and, as such, their distribution might constitute a hazard in the work environment (Albrecht *et al.*, 2006; Hannah and Thompson, 2008). As a result, production processes for nanomaterials may require further development and evaluation; with respect to recycling, washing, and recapturing (Robichaud *et al.*, 2005). Moreover, testing nanomaterials for degradation and leaching, emissions, and

comprehensive ecotoxicological studies may provide early warning of potential problems (Powell and Kanarek, 2006). However, very little is known about any potential environmental exposure and any human and environmental impacts (Hannah and Thompson, 2008; Dreher, 2004).

2. ATTITUDES TOWARDS SCIENCE AND TECHNOLOGY

2.1. Psychometric paradigm in risk perception

Understanding how the general public thinks about a broad range of risks has important implications for policy making and will help mitigate any concerns regarding emerging technologies. Recent research related to the psychological and social-cultural dimensions of risks has explored factors that influence individual and group perceptions of risk. These studies incorporate a wide range of theoretical perspectives and methodological approaches located in psychological and sociological thinking (Taylor-Gooby and Zinn, 2006). Mostly quantitative approaches to risk perception have been conducted for a wide range of issues, including potential health, environmental, and societal risks and the *safety* (Appendix 1) of these technologies (Alhakami and Slovic, 1994; Fischoff *et al.*, 1978; Gabrial and Nyshadham, 2008; Taylor-Gooby and Zinn, 2006). These "psychometric" studies often contrast attitudes of experts with those of the general public and incorporate predictors of trust, perceived benefits, and any potential consequences of the technologies (Slovic, 1987). In general, they recognize that there is a strong psychosocial component to risk perception that is otherwise overlooked by conventional approaches to risk assessment. The latter views potential impacts as *only* a combined function of the likelihood that a risk event will occur and the consequences it might have should the event occur, thereby ignoring that risk can have psychosocial and

cultural implications (Mauro and McLachlan, 2008). It is further argued that individual lay perceptions of risk vary with the uncertainty and dread associated with a given risk and its potential consequences (Taylor-Gooby and Zinn, 2006). Conceptual frameworks that incorporate these approaches provide excellent opportunities for developing insights into and understanding of consumer attitudes towards new technologies (Lee *et al.*, 2005; McCluskey *et al.*, 2004; Slimak and Dietz, 2006).

Another important approach to risk perception was initially developed by Mary Douglas and has been cultural in emphasis. The most important determinants of risk are thus strongly influenced by societal context rather than being individual in nature. Douglas and Wildavsky (1982) created a typology in which risk perceptions are shaped by cultural biases (i.e. the Grid-Group Cultural Theory or GGCT). Patterns of social organization that affect risk perceptions are affected either by grid (i.e. social rigidity) or group affiliation. The four possible types risk response are: individualist (low grid or rigidity, low group affiliation), fatalist (high grid, low group), egalitarian (low grid, high group) or hierarchical (high grid, high group). Although intuitive and appealing as an approach, the GGCT has not generally been supported by empirical data (Danielson, 2008).

Both these theoretical approaches have made extensive use of questionnaires, individual and group interviews, and manipulative social experiments. These methodologies typically do not rest on strong theoretical presuppositions about the field of study, often being primarily concerned with pragmatic issues such as risk communication (Taylor-Gooby and Zinn, 2006; Ripple, 2002). Although some of these approaches increasingly explore how risk perceptions vary among nations and regions,

such as North America and Europe (Gaskell *et al.,* 2005; Scheufele *et al.,* 2008), the United States and China (Bian and Keller, 1999), the United States and South Korea (Nayga *et al.*, 2006), the United States and Canada (Priest, 2006) and Canada, China, Japan, Norway, and the United States (McCluskey, 2004), the majority studies of the hazards and benefits associated with NT have begun to examine only expert (Besley, 2008) or lay (Bainbridge, 2002; Burri and Bellucci, 2008; Cobb and Macoubrie, 2004; Lee *et al.,* 2005; Macoubrie, 2006; Michelson and Rejeski, 2006; Nerlich *et al.*, 200; Siegrist *et al.*, 2008) attitudes and to contrast experts and lay perceptions (Savadori *et al.,* 2004; Siegrist *et al.*, 2007). Although this, in large part, reflects previous studies of risk perceptions regarding biotechnology (Fife and Rowe, 1996; Gaskell *et al.*, 2004; Levy *et al.*, 2008; Moon and Balasubramanian, 2004; Sparks and Shepherd, 1994; Williams and Hammitt, 2001), a much wider diversity of psychosocial, cultural, and demographic variables could also be incorporated.

The role of trust and confidence on public and expert risk perceptions is critical for managing the discourse surrounding the management of any emerging technology (Priest, 1995; Robbins, 2001; Siegrist, 2000). Thus far, the psychometric paradigm and its use of qualitative attributes of the risks themselves explain much more of the variance in risk perceptions than do cultural biases (Marris *et al.*, 1998). Some psychometric studies have attempted to bridge the gap between these bodies of literature by increasingly incorporating socio-demographic variables such as gender, age, income, education, race, religion, occupation, nationality and/or place of residence (Marris *et al.*, 1998; Taylor-Gooby and Zinn, 2006). Yet, the risk perception literature continues to be dominated by the psychometric paradigm, and when cultural approaches are mentioned at all, they are

usually cast in a negative light. Many studies continue to highlight the problems of cultural theory and indeed the complexity of culture for understanding risk perception. These problems include multiple functions of cultural meanings; the differentiated and dynamic nature of culture; and the unknown relationship of culture to environmental and socio-political factors because of the low level of explanatory power of the theory (Boholm, 1996; Miller, 1997; Sjöberg, 1995). In general, any risks that emerge from cultural diversity are seen as relatively intangible and thus unimportant or at least unworkable, because the relationship between culture and social structure in risk perception is not yet well understood (Prist *et al.*, 2003). Lennart Sjöberg thus argues that while the relationship between GGCT worldviews and risk perception may be statistically significant, the weak correlations do not explain enough of the variation in risk perceptions and cultural adherence, and instead suggests that risk perception is better tied to individual experiences rather than cultural values (Sjöberg, 1997).

2.2 Psycho-cultural dimensions of risk perception: the way forward

The psychometric paradigm and socio-cultural theory has each been promoted largely within its own disciplinary boundaries and in isolation from the other when characterizing and evaluating risk perception (Marris *et al.*, 1998). Although studies located in the psychological paradigm do incorporate social factors, they still emphasize individualist and realist accounts (Taylor-Gooby and Zinn, 2006). Yet, social context, culture, and institutions, such as industry, scientists, government, environmental groups, clearly exert a central influence on attitudes (Tansey, 2004; Peters *et al.*, 1997). Priest *et al* (2003) thus found, for example, that trust in institutions to be more important than knowledge of science in predicting levels of support or encouragement for biotechnology.

These theories show developments that may bridge the psychological and sociological disciplines as well as associations between cognition and emotions. These include cross-disciplinary research that explore the capacity of individuals to evaluate complex *costs* (Appendix 1) and benefits, as well as the role of gender that underlie differences in trust, dread, knowledge, utility, morality, risk, and encouragement surrounding risk (Tansey, 2004; Taylor-Gooby and Zinn, 2006; Priest *et al.*, 2003; Siegrist and George, 2000; Siegrist, 2000). The cultural approach which can influence decision-making (Leung and Bond, 1982) also provides important contributions to the understanding of risk perceptions and shows how underlying beliefs regarding trust and the environment shape attitudes; beliefs which are consistent within each world view (Marris *et al.*, 1998). Moreover, confidence in governments as well as scientists and the sciences as a whole also plays an important role in determining attitudes to biotechnology and NT, especially for experts (Siegrist *et al.*, 2007).

2.3 Risk Perception and NT

As with many other emerging technologies, the majority of risk studies regarding NT have examined public awareness and attitudes toward nanotechnology in the United States and in Europe. These studies show that most respondents, especially those studies that focus on lay people, are unfamiliar with the term nanotechnology, reflecting a corresponding lack of knowledge and understanding of this emerging technology and the need to evaluate any risks in the absence of detailed information (Cobb and Macoubrie, 2004; Gaskell *et al.*, 2005; Waldron *et al.*, 2006). Yet, the public remains generally optimistic, although largely unsure of any specifics about NT (Gaskell *et al.*, 2005;

Waldron *et al.*, 2006; European Commission, 2001). Thus, according to studies conducted in the US, 50% of the public indicate that nanotechnology will improve our way of life, while 35% remain unsure (Gaskell *et al.*, 2005). Likewise, 46% of Americans and 39% of Canadians agreed that nanotechnology 'will improve our quality of life over the next twenty years', with 57% of Americans and 64% of Canadians indicating they are 'not at all familiar' or 'not very familiar' with nanotechnology (Priest, 2003).

This optimistic outlook, in part, likely reflects the widely substantive benefits of NT in industrial productivity, economic growth, and international trade (Thomas and Sayre, 2005). It probably also reflects the relatively intangible nature of NT-associated risks, especially regarding human convenience and health, the latter aggravated by the relative absence of independent risk research (Dreher, 2004). This widespread optimism in turn reflects the substantial investment and promotion on the part of the governments and the nano-industry (ETC Group, 2003). It is further reflected in and perhaps, in turn, reflects optimistic media coverage, when the media covers NT at all (Wilkinson *et al.*, 2007). There has generally been little coverage of the potential risks of nanoparticles, especially in newspapers from the US, perhaps reflecting the relative absence of independent risk research and ineffective regulation regarding NT (Kulve, 2006; Wilkinson *et al.*, 2007).

Unlike the first generation of biotechnology, which has focused on benefits to farmers, the wide appeal of NT also reflects the many ostensible benefits that these products will provide for consumers. Yet the public in Europe is somewhat less supportive of the technology (29% indicating their support and 53% unsure) compared to North Americans (Gaskell *et al.,* 2005). This consumer distrust of new technologies has

likely been influenced by other concomitant controversies, such as bovine spongiform encephalopathy (BSE) in Great Britain and France, and the wide scale resistance to genetically modified (GM) crops throughout western Europe. These controversies have, in turn, contributed to a decline in trust in governments by European consumers and farmers (Caplan, 2000) and perhaps reflect the vital importance that people attribute to their food (Henson *et al.*, 2007; Hwang, 2008). Alper (2006) indicated that lay people in Europe who are aware of nanotechnology have some concern about health and environmental safety and that research should be more specific in approach, identifying which nanomaterials might have risks that outweigh potential benefits.

Social trust and distrust characteristics can be used to compare societal responses to emerging technologies. Economic, cultural, and political climates vary among nations, and these cross-cultural differences might be revealed by more explicitly incorporating the contributions of cultural theory (Priest *et al.*, 2003). Yet, almost all cross-cultural comparisons are restricted to Europe and North America, and large-scale public-risk-perception studies are still relatively rare for other countries, especially those in the Global South. Yet, one notable study found that perceptions of financial risks in respondents from the Netherlands and the U.S differed from those in Hong Kong and Taiwan, despite all having a common Chinese cultural heritage (Bontempo *et al.*, 1997). The latter were more sensitive to the magnitude of potential losses and these concerns were less mitigated by the probability of positive outcomes, with respect to their fear of failure relative to their desire to achieve (Bontempo *et al.*, 1997). In another study, American and Chinese perceptions risky health and safety decisions were evaluated (Bian and Keller, 1999). Although respondents had quite similar perceptions of fairness

regarding these actions, they made quite different decisions in equivalent situations because the issues underlying any decisions varied between Chinese and American participants.

2.4 Public and expert attitudes towards science and technology

Recent developments associated with nanotechnology are located within a broader historical context surrounding all emerging technologies. In the twentieth century, mechanical, chemical, and biological technologies around the world have come to play a central role in industry, especially intensive agriculture and the use of pesticides and chemical fertilizers (Horne and McDormott, 2001; Blaine and Powell, 2001). Governments have promoted this industry, in part, because they anticipate there will be a resulting increase in jobs and land productivity (Troughton, 2005). Since the 1970s, many leading scientists working in emerging technologies have expressed idealistic visions and expectations that would results from technological advances, in effect representing a second industrial revolution that emerged after and reflected technology developed through the Second World War (Grove-White *et al.*, 2004). Following the adoption of biotechnology which preceded NT in market usage, over 20 countries around the world now use GM crops, which have facilitated fundamental changes in agro-production (Hwang, 2008). The anticipated benefits of these crops have been highlighted by industry and include increases in yields and efficacy of weed management as well as declines in the use of pesticides and fuel, and reduced soil erosion (Brooks and Barfoot, 2005; Huang *et al.*, 2005).

With respect to biotechnology, the level of consumer understanding and concern

associated with GM food and policies is still unclear, even though many countries such as Korea and Japan have already launched labeling systems and regulations regarding GM ingredients and products (Hwang, 2008). Moon and his colleagues (2004) identified that consumer attitudes towards and acceptance of GM food were influenced by trust of regulatory agencies, scientific knowledge and awareness of technological as well as demographics. Indeed, women whom were largely responsible for household food purchases were far more likely to focus on risks than men and to expected industry to be honest and forthcoming about both risks and benefits (Rejeski, 2006). Yet public concerns about potential environmental and health risks arising from biotechnology have not abated, especially regarding food, and consumer advocates around the world continue to focus attention on the use of biotechnology and have in many cases explicitly oppose its use any where (Cronin, 2004; Moon and Balasubramanian, 2004; Siegrist, 2008).

Likewise, proponents of NT argue that the technology will have substantial benefits for our way of life in the future. Governments and industry generally have positive outlooks on these new technologies, which promise to bring about significant societal benefits and associated transformation of manufacturing, products and services, human abilities and economic achievements, and even social relationships (Roco, 2005; Royal Society, 2004). In part reflecting these huge expectations, investments in the value of nanotechnology by governments and industry are steadily increasing and now exceed $30 billion US. By 2015, this investment is projected to exceed $1 trillion US worldwide (Sharpe, 2006).

Yet others are more cautious if not condemning of this technology. Many feel there is need to consult the public early in decision-making and on a regular basis, which may

help reduce the likelihood that the public will subsequenıdes as they did towards biotechnology (Metha, 2004; Priest, 20ılusive approach to decision-making would enable a greater dive perhaps allow consumers to influence the direction that tırt anticipating the varied adoption rates of other emerging tM crops that have been observed among nations (Cronin, 2(Balasubramanian, 2004).

3. ATTITUDES TOWARDS NANOTECHNOLOGY S

3.1. Public and expert awareness to risks associated with

While more than $32 billion has been invested by ats into this technology worldwide, many scientists working on ı evidence of any important environmental and human heandy and Shaw, 2007; Rejeski, 2006). The industries likewise nanoproducts currently available on the market (Roszek her experts are less optimistic, recognizing that risks may alr applications, to say nothing of NT in the future (Burri, 2(

These expert views regarding safety implications ar probability of harm (Cohen, 1985) unlike public attitudesder and more complex in nature. The latter tend to focus on ıentific information regarding potential environmental and huma37). Thus, the UK Small Talk (2006), a British initiative to geging technologies, concluded that "public concerns about safeıs of the technology itself but almost wholly in terms of the soensure

:n though many countri
and regulations regard
:olleagues (2004) ident
were influenced by trus
of technological as we
nsible for household fo
n and to expected indus
:jeski, 2006). Yet publi
ırising from biotechnol
ɔcates around the worlc
n many cases explicitly
ınian, 2004; Siegrist, 2(
gy will have substantial
ry generally have posit
ing about significant sc
products and services,
ationships (Roco, 2005
, investments in the val
/ increasing and now e:
:d $1 trillion US world

ıis technology. Many fe
l on a regular basis, wh

that hazard will be identified and products regulated" (UK Small Talk, 2006). Interest of public awareness in the application of new technologies, however, remains limited to a few countries such as Australia, the United Kingdom (UK), New Zealand , Germany, and the United States of America (US) (Cobb and Macoubrie, 2004; Commonwealth of Australia, 2005; Council for Science and Technology, 2006; Cronin, 2004 ; Jackson *et al.*, 2005; Nanologue, 2005).

3.2. Research of public participation toward nanotechnology

Public acceptance of NT and its applications ultimately depends on public attitudes and confidence in the institutions that are proponents of the technology (Ebbesen, 2008; Macoubrie, 2005). In the 1980s, it was increasingly recognized that public understanding of science and technology is generally seen as desirable in that it would reduce controversies surrounding emerging technologies (Bruntland, 1987; Commission of the European Communities, 2000). These controversies thus are seen as reflecting an underlying lack of knowledge, and, in turn, manifest themselves as consumer fear. These increases in understanding could ostensibly be best achieved by more effective education of the public and communication and the active participation of scientists in this process (Royal Society, 1985). In recent years, there has been an increased focus on the active role of the public in decision-making regarding NT and other technologies, this occurring "upstream" in the process. It is thus becoming increasingly popular to encourage the role of the public attention in science and policy and exchanges have been held in many countries to facilitate communication and interaction among industry, civil organizations, and the mass media. This multi-stakeholder involvement is seen as an essential key for

the responsible development of the potential of nanoproducts. Any risks can be addressed by specific assessments and evaluation, which includes greater transparency and discourse, pre-market testing of nanoproducts by industry or governments, third-party testing, and independent research (Lösch, 2006; Rejeski, 2006; Roco, 2005).

Research conducted around the globe, including the US (Council for Science and Technology, 2006), New Zealand (Cronin, 2004), the United Kingdom (Jackson *et al.*, 2005), Australia (Commonwealth of Australia, 2005) and Germany (Nanologue, 2005), shows that these more inclusive decision-making processes, which can take the form of "nanojuries", "nanofora", and "nanologues", generally act to mitigate public fears, including those associated with potential "regulatory failures" (Bowman, 2007; Cook and Fairweather, 2005; Kearnes *et al.*, 2006; Madison, 2005; Rogers-Hayden and Pidgeon, 2006; TA-Swiss, 2006). In part, this is achieved because the public is better acquainted with the decision-making processes undertaken by governments and the information that these institutions use to inform their priorities. While increasing the input and sense of influence that non-experts have in priority setting, these processes arguably also act to increase the diversity of opinions surrounding these technologies and thus result in better decisions.

Since September 2005, the Swiss centre for Technology Assessment (TA-Swiss) has organized and developed a number of instruments (i.e. the PubliForum, the PubliFocus, and the PubliTalk) in order to facilitate citizen discussion forums of emerging technologies, and included the public in deliberate discourses surrounding decision-making. The PubliForum, for example, usually consists of about 30 individuals whom are socio-demographically diverse. The forum have been held on topics such as

biotechnology and nutrition, organ transplantation, research on humans, and, of course, nanotechnology (Burri, 2007). By considering the social, political, and environmental implications of emerging technologies, the PubliFocus involved governmental and nongovernmental stakeholders from different fields, such as science, nano-industry, farmer associations, consumer organizations, and NGOs (TA-Swiss, 2006). The consensus conferences aim to learn about the attitudes of both stakeholders and other citizens and the PubliTalk designed as afternoon discussions attempts to bridge differences between experts and laypeople and has resulted in greater participant understanding of the underlying science and technology (Burri, 2007; Burri and Bellucci, 2008). The challenge, of course, is how to upscale these normally small-group processes to inform large scale decision-making surrounding emerging technologies (Hodge and Bowman, 2007).

Public policy processes are thus increasingly focused on questions surrounding potential risks to the environment and human health represented by NT. These are being developed in order to further develop science and technology but within a wider context of the public dimensions of NT (Doubleday, 2007). Moreover, Macoubrie (2005) indicated that the public does not seem to be fearful of NT itself, but is highly aware of past problems, including regulatory, environmental, and human health errors surrounding new technologies. The errors act to shape the gauging of risks, and any new information resonates and even reinforces pre-existing attitudes and judgments. These past decisions and the processes that underlie them are the focus of research that is an attempt to identify approaches that are as new as the technology they focus on.

REFERENCES

Alhakamo, A. S. and Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis*, 14, 1085-1096.

Alper, J. (2006). Nano in the public eye. *Nano Science and Technology Institute*. Available at: http://www.nano-and-society.org/news/06/august.html

Albrecht, M. A., Evans, C. W., and Raston, C. L. (2006). Green chemistry and health implications of nanoparticles. *Green Chemistry*, 8, 417-432.

Bainbridge, W. S. (2002). Public attitudes toward nanotechnology. *Journal of Nanoparticle Research*, 4, 561-570.

Balshaw, D. M., Philbert, M., and Suk, W. A. (2005). Research strategies for safety evaluation of nanomaterials, Part III: Nanoscale technologies for assessing risk and improving public health. *Toxicological Sciences*, 88, 298-306.

Blaine, K. and Powell, D. (2001). Communication of food-related risks. *AgBioForum*, 4, 179-185.

Besley, J. C., Kramer, V. L., and Priest, S. H. (2008). Expert opinion on nanotechnology: Risks, benefits, and regulation. *Journal of Nanoparticle Research*, 10, 549-558.

Bian, W. and Keller, L. R. (1999). Chinese and American agree on what is fair, but disagree on what is best in societal decisions affecting health and safety risks. *Risk Analysis*, 19, 439-452.

Biel, A. and Dahlstrand, U. (1995). Risk perception and the location of a repository for spent nuclear fuel. *Scandinavian Journal of Psychology*, 36, 25-36.

Boholm, A. (1996). The cultural theory of risk: an anthropological critique. *Ethnos*, 61, 64-84.

Bontempo, R.N., Bottom, W.P., and Weber, E. U. (1997). Cross-cultural differences in risk perception: A model-based approach. *Risk Analysis*, 17, 4795-489.

Bowman, D.M. and Hodge, G. A. (2007). A small matter of regulation: An international review of nanotechnology regulation. *The Columbia Science and Technology Law Review,* 8, 1-36.

Brookes, G. and Barfoot, P. (2006). GM crops: The first ten years- the global socio-economic and environmental impacts. *International Service for the Acquisition of Agri-biotech Application (ISAAA),* 36, 1-116. Available at: http://www.isaaa.org/Resources/Publications/briefs/36/download/isaaa-brief-36-2006.pdf

Bruntland, G. (ed.), (1987). Our common future: The World Commission on Environment and Development, Oxford, Oxford University Press.

Burri, R. V. (2007). Deliberating risks under uncertainty: Experience, trust, and attitudes in a Swiss nanotechnology stakeholder discussion group. *Nanoethics*, 1, 143-154.

Burri, R.V. and Bellucci, S. (2008). Public perception of nanotechnology. *Journal of Nanoparticle Research,* 10, 387-391.

Caplan, P. (2000). Eating British beef with confidence: A consideration of consumers' responses to BSE in Britain. In P. Caplan (Ed.), Risk Revisited, 184–203.

Cobb, M. D. and Macoubrie, J. (2004). Public perceptions about nanotechnology: Risks, benefits and trust. *Journal of Nanoparticle Research,* 6, 395-405.

Cohen, B. L.(1985). Criteria for technology acceptability. *Risk Analysis*, 5, 1-2.

Commission of the European Communities (2000). Commission working document: Science, society and the citizen in Europe, Brussels. Available at: http://ec.europa.eu/research/area/science-society-en.pdf

Commonwealth of Australia. (2005). Senate Community Affairs reference committee-inquiry into workplace exposure to toxic dust-Terms of reference. Canberra, Australia: Commonwealth Government. Available at: http://www.aph.gov.au/Senate/committee/clac_ctte/completed_inquiries/2004-07/toxicdust/report/c01.htm

Cook, A. J. and Fairweather, J.R. (2005). Nanotechnology-ethical and social issues: results from New Zealand focus groups. Research Report No. 281. Canterbury, New Zealand: Lincoln University. Available at: http://www.lincoln.ac.nz/story_images/1330_rr281_s4140.pdf

Cronin, K. E. (2004). From biotech to nanotech-Enhancing deliberative processes for science and technology innovation. Victoria University of Wellington, Wellington, New Zealand. Available at: http://www.engagingcommunities2005.org/abstracts/Cronin-Karen-final.pdf

Danielson, S. (2008). Is cultural theory useful? A pragmatist application to wildfire risk, Available at: http://debitage.net/academic/GGCTuseful-webdraft.pdf

Doubleday, R. (2007). Risk, public engagement and reflexivity: Alternative framing of the public dimensions of nanotechnology. *Health, Risk, and Society*, 9, 211-227.

Douglas, M. and Wildavsky, A. (1982). Risk and culture: An essay on the selection of technological and environmental dangers. Berkeley; Los Angeles; London:

University of California Press.

Dreher, K. L. (2004). Health and environmental impact of nanotechnology: Toxicological assessment of manufactured nanoparticles. *Toxicological sciences*, 77, 3-5.

Ebbesen, M. (2008). The role of the humanities and social sciences in nanaotechnology research and development. *Nanoethics*, 2, 1-13.

ETC Group (2003). The big down: Atomtech-tehnologies converging at the nanoscale. ETC group, Winnipeg, Manitoba, Canada. Available at: http://www.etcgroup.org/upload/publication/171/01/thebigdown.pdf

European Commission. (2001). Eurobarometer survey on europeans, science, and technology. Brussels: European Commission. Available at: http://ec.europa.eu/research/press/2001/pr0612en-report.pdf

European Commission, Community Health and Consumer Protection. (2004). Nanotechnologies: A preliminary risk analysis on the basis of a workshop organized in Brussels on 1–2 March 2004 by the Health and Consumer Protection Directorate General of the European Commission. Available at: http://europa.eu.int/comm/health/ph_risk/events_risk_en.htm.

Fife-Schaw, C. and Rowe, G. (1996). Public perceptions of everyday food hazards: A psychometric study. *Risk Analysis*, 16, 487-500.

Fischhoff, B., Slovic, P., and Lichtenstein, S. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Journal of Policy Science,* 9, 127-152.

Gabrial, I. J. and Nyshadham, E. (2008). A cognitive map of people's online risk perceptions and attitudes: An empirical study, Proceeding of the 41st Hawaii International Conference on System Sciences. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4438979 &isnumber=4438696

Gaskell, G., Ten Eyck, T. T., Jackson, J., and Veltri, G. (2005). Imaging nanotechnology: Cultural support for technological innovation in Europe and the United States. *Public Understanding of Science*, 14, 81-90.

Gaskell, G., Allum, N., Wagner, W., Kronberger, N., Torgersen, H., Hampel, J., and Bardes, J. (2004). GM Foods and the misperception of risk perception, *Risk Analysis,* 24, 185-194.

Grove-White, R., Kearens, M., Miller, P., Macnaghten, P., Wilsdon, J., and Wynne, B. (2004). Bio-to-Nano?: Learning the lessons, interrogating the comparison. Institute for Environment, Philosophy and Public Policy, Lancaster University and Demos.

Available at:
http://www.nanoandsociety.com/ourlibrary/documents/bio+to+nano.pdf

Hannah, W. and Thompson, P.B. (2008). Nanotechnology, risk and the environment: A review. *Journal of Environmental Monitoring*, 10, 291-300.

Hanson, S., Annou, M., Cranfield, J., Ryks, J., and Herath, D. (2007). Understanding consumer attitudes towards food technologies in Canada. International Food Economy Research Group, Department of Food, Agricultural and Resource Economics, University of Guelph. Available at: http://www.inferg.ca/workingpapers/W_P13.pdf

Hayakawa, H., Fischbech, P. S., and Fischhoff, B. (2000). Traffic accident statistics and risk perceptions in Japan and the United States. *Accident Analysis and Prevention,* 32, 827-835.

Hodge, G. A. and Bowman, D. M. (2007). Engaging in small talk: Nanotechnology policy and dialogue processes in the UK and Australia. *The Australian Journal of Public Administration*, 2, 223–237. Available at: http://www3.interscience.wiley.com.proxy2.lib.umanitoba.ca/cgi-bin/fulltext/18512038/PDFSTART

Hoet, P. H. M., Bruske-Hohlfeld, I., and Salata, O. V. (2004). Nanoparticles-known and unknown health risks. *Journal of Nanotechnology,* 2, 1-19.

Horne, J. E. and McDermont, M. (2001). The next green revolution: Essential steps to healthy, sustainable agriculture. New York: Food Products Press.

Huang, J., Hu, R., Rozelle, S., and Pray, C. (2005). Insect-resistant GM rice in farmers' fields: Assessing productivity and health effects in China. *Science*, 308, 688-690.

Hwang, S. W. (2008). Farmer and consumer attitudes toward GM foods in South Korea. University of Manitoba, Manitoba.

Jackson, R., Barbagallo, F., and Haste, H. (2005). Strengths of public dialogue on science-related issues. *Critical Review of International Social and Political Philosophy*, 8 , 349-358.

Kalaichelvan, P. T. (2008). Size matters much that is nano. Available at: http://ptkalaichelvannotebook.blogspot.com/2008/01/size-matters-much-that-is-ano.html

Kearnes, M., Macnaghten, P., and Wilson J. (2006). Governing at the nanoscale: People, policies and emerging technologies. Demos, London. Available at: http://www.demos.co.uk/files/governingatthenanoscale.pdf?1240939425

Kulve, H. T. (2006). Evolving repertoires: Nanotechnology in daily newspapers in the Netherlands. *Science as Culture*, 15, 367-382.

Kuzma, J. and VerHage, P. (2006). Nanotechnology in agriculture and food production. Washington, DC: Woodrow Wilson International Center for Scholars. Available at: http://www.nanotechproject.org/file_download/files/PEN4_AgFood.pdf

Lee, C. J., Scheufele, D. A., and Lewenstein, B. V. (2005). Public attitudes toward emerging technologies. *Science Communication,* 27, 240-266.

Leung, K. and Bond, M. H. (1982). How American and Chinese reward task-related contributions: A preliminary study. *Psychologia*, 25, 2-9.

Levy, A. S., Choiniere, C. J., and Fein, S. B.(2008). Practice-specific risk perceptions and self-reported food safety practices. *Risk Analysis*, 28, 749-761.

Li, X., Chen, H., Dang, C., Lin, Y., Larson, C. A., and Roco, M. (2008). A longitudinal analysis of nanotechnology literature: 1976-2004. *Journal of Nanoparticle Research,* 10, 3-32.

LÖsch, A. (2006). Means of communicating innovations: A case study for the analysis and assessment of nanotechnology's futuristic visions. *Science, Technology and Innovation Studies,* 2, 103-125.

Mauro, I. J. and McLachlan, S. M. (2008). Farmer knowledge and risk analysis: Post release evaluation of herbicide-tolerant canola in western Canada. *Risk Analysis*, 28, 463-476.

McCluskey, J. J., Grimsrud, K. M., and Wahl, T. I. (2004). Comparison of consumer responses to genetically modified foods in Asia, North America, and Europe. *Regulating Agricultural Biotechnology: Economics and Policy*, Chapter 11, 227-240.

Macoubrie, J. (2005). Informed public perceptions of nanotechnology and trust in Government. Washington DC: Project on Emerging Nanotechnology. Available at: http://www.wilsoncenter.org/news/docs/macoubriereport.pdf

Macoubrie, J. (2006). Nanotechnology: Public concerns, reasoning and trust in government. *Public Understanding of Science,* 15, 221-241.

Madison. (2005). Report of the Madison area citizen consensus conference on nanotechnology, Available at: http://www.nanocafes.org/files/consensus_conference_report.pdf

Marris, C., Langford, I. H., and O'Riordan, T., (1998). A quantitative test of the cultural theory of risk perceptions: Comparison with the psychometric paradigm. *Risk*

Analysis, 18, 635-647.

Mehta, M. D. (2004). From Biotechnology and nanotechnology: What can we learn from earlier technology? *Technology and Society,* 24, 34-39.

Michelson, E. S. and Rejeski, D. (2006). Falling through the cracks? Public perception, risk, and the oversight of emerging nanotechnologies. *Technology and Society*, 1-17. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsptp=&arnumber=4375890&isnumber=4375875

Miller, J.G. (1997). Theoretical issues in Cultural Psychology. In: J.W. Berry, Y.H Poortinga. and J.A. Pandey (Eds.). *Handbook of cross-cultural psychology. Volume1 Theory and method.* Needham Heights, MA: Viacom Company.

Moon, W. and Balasubramanian, S. K. (2004). Public attitudes toward agrobiotechnology : The mediating role of risk perceptions on the impact of trust, awareness, and outrage. *Review of Agricultural Economics*, 26, 186-208.

Nanologue. (2005). Nanologue-Facilitating dialogue between research, business and society. Paper presented at *EuroNanoForum*, Edinburgh, Scotland.

Nayga, R. M., Fisher, M. G., and Onyango, B. (2006). Acceptance of genetically modified food: Comparing consumer perspective in the United States and South Korea. *Agricultural Economics,* 34, 331-341.

Nerlich, B., Clarke, D. D., and Ulph, F. (2007). Risks and benefits of nanotechnology: How young adults perceive possible advances in nanomedicine compared with conventional treatments. *Health, Risk & Society,* 9, 159-171.

Oltedal, S., Moen, B., Klempe, H., and Rundmo, T. (2004). Explaining risk perception. An evaluation of cultural theory. Rotunde. Available at: http://www.svt.ntnu.no/psy/Torbjorn.Rundmo/Cultural_theory.pdf

Peters, R. G., Covello, V. T., and McCallum, D. B. (1997). The determinants of trust and credibility in environmental risk communication: An empirical study. *Risk Analysis*, 17, 43-54.

Powell, M. C. and Kanarek, M. S. (2006). Nanomaterial health effects-part 1: Background and current knowledge. *Wisconsin Medical Journal*, 105, 16-20.

Powell, M. C. and Kanarek, M. S. (2006). Nanomaterial health effects-part 2: Uncertainties and recommendations for the future. *Wisconsin Medical Journal*, 105, 18-23.

Priest, S. H. (2006). The North American opinion climate for nanotechnology and its

products: opportunities and challenges. *Journal of Nanoparticle Research*, 8, 563-568.

Priest, S. H. (1995). Information equity, public understanding of science and the biotechnology debate. *Journal of Communication*, 45, 39-54.

Priest, S. H., Bonfadelli, H., and Rusanen, M. (2003). The "trust gap" hypothesis: predicting support for biotechnology across national cultures as a function of trust in actors. *Risk Analysis*, 23, 752-76.

Rippl, S. (2002). Cultural theory and risk perception: a proposal for a better measurement. *Journal of Risk Research*, 5, 147-165.

Rejeski, D. (2006). FDA and nanotechnology: Public perceptions matter. Project on Emerging Nanotechnologies, 1-11. Available at: http://www.nanotechproject.org/file_download/files/RejeskiFDA.pdf

Robichaud, C. O., Tanzil D, Wellenmann U., and Wiesner, M. (2004). Relative risk analysis of several manufactured nanomaterials: An insurance industry context. *Environmental Science and Technology*, 39, 8985-8994.

Robbins, R. (2001). Overburdening risk: Policy frameworks and the public uptake of gene technology debate. *Public Understanding of Science*, 10, 19-36.

Roco, M. C. (2004). Nanoscale science and engineering: Unifying and transforming tools. *ALCHE Journal*, 50, 890-897. Available at: http://www.nsf.gov/crssprgm/nano/reports/mcr_04-0101_visionnt@aiche_final.pdf

Roco, M.C. (2005). The emergence and policy implications of converging new technologies integrated from the nanoscale. *Journal of Nanoparticles Research*, 7, 129-143.

Rogers-Hayden, T. and Pidgeon, N. (2006). Reflecting upon the UK's citizens' jury on nanotechnologies: NanoJury UK. *Nanotechnology Law and Business* (May/June), 167-178.

Roszek, B., de Jong W. H., and Geertsma, R.E. (2005). Nanotechnology in medical applications: State-of-the-art in materials and devices, *RIVM report.* Available at: http://lamp.tu-graz.ac.at/~hadley/nanoscience/references/RIVM.pdf

Royal Society. (2004). Nanoscience and nanotechnologies: Opportunities and uncertainties. Royal Society and Royal Academy of Engineering, London. Available at: http://www.nanotec.org.uk/finalReport.htm

Sanguansri, P. and Augustin, M. A. (2006). Nanoscale materials development-a food industry perspectives. *Trends in Food Science and Technology*, 17, 547-556.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., and Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis*, 24, 1289-1299.

Sharpe, M. (2006). Small wonders, big future: The development of environmental nanotechnology. *Journal of Environmental Monitoring,* 8, 235-239.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science and Technology,* 19, 603-608.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis*, 20, 195–204.

Siegrist, M. and George, C. (2000). Perceptions of hazards: The role of social trust and knowledge. *Risk Analysis*, 20, 713–719.

Siegrist, M., Keller, C., Kastenholz, H., Frey, S., and Wiek, A. (2007). Lay people's and experts' perception of nanotechnology hazards. *Risk Analysis*, 27, 59-69.

Sjöberg, L. (1995). Explaining risk perception: An empirical and quantitative evaluation of cultural theory, Rhizikon: Risk Research Reports, 22, Centre for Risk Research, University of Stockholm, Sweden.

Sjöberg, L.(1997). Explaining risk perception: An empirical evaluation of cultural theory. *Risk Decision and Policy,* 2, 113-130.

Slimak, M. W. and Dietz, T. (2006). Personal values, beliefs, and ecological risk perception. *Risk Analysis,* 26, 1689-1705.

Slovic, P. (1987). Perception of risk. *Science,* 236, 280-285.

Small Talk (2006). Small talk: Project report (London: Think-Lab)

Sparks, P. and Shepherd, R. (1994). Public perceptions of the potential hazards associated with food production and food consumption: An empirical study. *Risk Analysis*, 14, 799-806.

Swiss, Re. (2004). Nanotechnology: Small matter, many unknown. Swiss Reinsurance Company, Zurich. Available at: http://www.swissre.com/INTERNET/pwsfilpr.nsf/vwFilebyIDKEYLu/ULUR-5YNGET/$FILE/Publ04_Nanotech_en.pdf

TA-Swiss (2006). Public reactions to nanotechnology in Switzerland. Report on publifocus discussion forum "nanotechnology, health, and the environment." TA-P 8/2006. Centre for Technology Assessment at the Swiss Science and Technology

council, Bern

Tansey, J. (2004). Risk as politics, culture as power. *Journal of Risk Research*, 7, 17-32.

Taylor-Gooby, P. and Zinn, J.O. (2006). Current directions in risk research: New developments in psychology and sociology. *Risk Analysis*, 26, 397-411.

Thomas, T., Thomas K., Sadrieh, N., Savage, N., Adair, P., and Bronaugh, R. (2006). Research strategies for safety evaluation of nanomaterials, Part VII: Evaluating consumer exposure to nanoscale materials. *Toxicological Sciences*, 91, 14-19.

Thomas, K. and Sayre, P. (2005). Research strategies for safety evaluation of nanomaterials, Part I: Evaluating the human health implications of exposure to nanoscale materials. *Toxicological Sciences*, 87, 316-321.

Troughton, M. (2005). Fordism rampant: The model and reality, as applied to production, processing and distribution in the North American agro-food system. In Mauro, L. J. (2008). Riding the risk wave: Farmer knowledge and experience with GM crops in the Canadian prairies, the University of Manitoba (Ph. D thesis).

Tsuji, J. S., Maynard A. D., Howard, P. C., James, J. T., Lam C., Warheit, D. B., and Santamaria, A. B. (2006). Research strategies for safety evaluation of nanomaterials, Part IV: Risk assessment of nanoparticles. *Toxicological Sciences*, 89, 42-50.

U.S. Department of Energy. (2006). The scale of things chart. The Office of Basic Energy Sciences. Available at: http://www.science.doe.gov/bes/scale_of_things.html

Waldron, A. M., Spencer, D., and Batt C. A. (2006). The current state of public understanding of nanotechnology. *Journal of Nanoparticles Research*, 8, 569-575.

Wilkinson, C., Allan, S., Anderson, A., and Petersen, A. (2007) From uncertainty to risk?: Scientific and news media portrayals of nanoparticles safety. *Journal of Health, Risk & Society*, 9, 145-157.

Williams, P. R. D. and Hammitt, J. K. (2001). Perceived risks of conventional and organic produce: pesticides, pathogens, and natural toxins. *Risk Analysis*, 21, 319-330.

Wilson, J. (2004). The Politics of small things: nanotechnology, risk, and uncertainty. *Technology and Society Magazine*, 23, 16-21.

CHAPTER III: Attitudes towards Science and Technology and Implications for Perceptions Regarding Nanotechnology

3.1 ABSTRACT

Although nanoproducts are fast being developed and released on the market in both Canada and South Korea, few studies have adequately explored the implications for perceptions regarding this new technology in either country, much less compared how they vary between the two. This study is the first to compare public and expert attitudes between North America and Asia. The objectives in this study were: to assess public and expert attitudes towards NT and to assess to what degree they reflect underlying trust in science and governments; to contrast the attitudes of experts with those of the public; and to explore to what degree these any variation in attitudes are shaped by cultural differences between Canada and South Korea.

A questionnaire was designed that assessed attitudes toward science and technology, the environmental, health and social implications of nanotechnology, and possible responses to any risks associated with NT. It consisted of seven-point Likert scaled and open-end questions. The survey was conducted from November, 2007 until May, 2008. In total, 975 questionnaires were completed: 513 in Canada and 462 in Korea. Sampling was stratified between students (n=488), the general public (n=398), and experts (n=89).

Overall, most respondents from Canada and especially Korea (84% vs. 94%, respectively) had heard of NT but much fewer (24% vs. 16%) indicated they were knowledgeable of the technology. Respondents from both countries were highly optimistic about the technology, especially those from Korea. Little difference existed between the two countries regarding expertise of NT, trust in technology, attitudes

towards the environment, and concern regarding public input. Generally, respondents were most excited about the potential of NT for human health, especially for Canada, followed by environmental benefits. Respondents sorted out into three groups: opponents that were highly critical of NT, proponents that were highly supportive and conditional proponents that seemed to evaluate benefits against any potential risks before making decisions. Lay respondents from both countries that were male were less likely to be critical than their female counterparts.

Experts generally had more favorable attitudes towards NT, were more likely to be men, and were more likely to be trained in the sciences, especially engineering and the life sciences. Respondents were much more concerned about human health risks than environmental risks, especially those who had been educated in social sciences and the humanities. Of the independent variables that shaped attitudes towards NT, concern regarding social impacts and the environment, human health, public input, and trust in scientist, science, and technology were very important. Expertise in NT, levels of formal education, academic specialization, gender, age, religion, marriage status, and financial wellbeing were still meaningful although less important.

3.2 INTRODUCTION

Over the last 50 years, there has been increased excitement regarding new technologies that promise to change the lives of all humans for the better. Initially focusing on the promise of biotechnology, especially for agriculture, this excitement has grown to include information technology and most recently nanotechnology (NT) (Amin *et al.*, 2007; Brooks and Barfoot, 2005; Roco, 2005). Yet these new technologies have also met with much resistance. The ongoing "food fight" regarding biotechnology, between governments and industry on one hand and consumer and environmental groups on the other, continues unabated (Cronin, 2004; Frewer, 2003; Gaskell *et al.*, 2004; Mauro and McLachlan, 2008; Moon and Balasubramanian, 2004; Sjöberg, 2004). Although nanoproducts continue to be developed and marketed around the world, there has been a corresponding groundswell of resistance to this technology. These act to encourage the role of the public regarding science and policy, and, in the absence of adequate information on any associated risks, only serve to aggravate public concerns (Cook and Fairweather, 2005; Kearnes *et al.*, 2006; Madison, 2005; Rogers-Hayden and Pidgeon, 2006; TA-Swiss, 2006).

However, the great promise of NT continues to dominate public discourse regarding this technology, and the anticipated benefits are generally seen as far reaching and diverse in nature (Grove-White *et al.*, 2004). Proponents claim that rapid improvements in nanotechnology have already produced products that are better in quality; that have significant social benefits; and that represent improvements in transforming tools, new products and services (e.g. pharmaceutical genomics, neuromorphic equipment, regenerative medicine, biochips with complex functions, multiscale molecular systems,

electronic devices, software for multiscale simulations, processes, and systems, and new flight (Roco, 2005; Royal Society, 2004). Most current applications of nanotechnology incorporate a wide range of substances including titanium dioxide (TiO2) and zinc oxide (ZnO) which might represent key routes for skin exposure (Sharpe, 2006). There nanoparticles are used in products including sunscreens and cosmetics; specialised coatings such as in self-cleaning windows; scratch-resistant car bumpers, tyres, film development; catalysts in the petrochemical industry; pharmaceuticals; sporting goods; and electronics (Roszek, de Jong, and Geertsma, 2005; Sharpe, 2006; Wood, 2005).

Reflecting these expectations, substantial investments have been made in this technology, exceeding US$30 billion globally by governments alone in 2003. Indeed, the value of nanotech-related products is anticipated to exceed $1 trillion worldwide by 2015 (Sharpe, 2006). Under the National Nanotechnology Initiative (NNI) in the US, the 21st Century Nanotechnology Research & Development Act of 2003 has set out an action plan for nanotechnology-related research and development, which focuses on sustaining world-class research; facilitating technology transfer; developing infrastructure in research and education; and supporting the responsible development of nanotechnology (Merzbacher, 2005).

Yet there are growing concerns that these nano-materials may have unintentional and adverse environmental, social, and human health impacts (Health and Consumer Protection, 2004; ETC Group, 2007). Issues of scale, usually ranging in size from 1 to 100 nanometers (nm), are seen as especially important, as properties on nanomaterials may behave differently at the atomic level than otherwise equivalent coarse-scale materials (Roszek, de Jong, and Geertsma, 2005). Use of nanoparticles offer potential

exposure to humans and environment that could occur through inhalation, ingestion, skin penetration, and accumulated contamination including water, air, nutrients or oxygen. This may occur, in part, because nanoparticles will penetrate cells more readily than larger particles and do not escape as readily into the air (Hoet *et al.*, 2004; Monit, 2006; Powell and Kanarek, 2006; Wilson, 2004). Thus, inhaled nanoparticles with higher surface-to-mass area may exhibit more potent toxicological behavior or their dose-responses may be more related to surface areas than concentration or mass (Hannah and Thompson, 2008).

Yet the extensive psychometric studies show that risk also has important psychological and cultural dimensions. Mostly quantitative assessments of risk perceptions have been conducted for diverse concerns such as health, finance, naturally occurring hazards, and technology (Gabrial and Nyshadham, 2008; Alhakami and Slovic, 1994; Fischoff *et al.,* 1978). Many studies have contrasted attitudes of experts with those of the general public. Predictors of trust and perceived benefits influence attitudes regarding novel technology as do any uncertainty and dread surrounding potential consequences (Slovic, 1987). Confidence in government is also an important variable of perceived risks associated with nanotechnology (Siegrist *et al.*, 2007).

The majority of risk perception studies regarding NT have been conducted in the United States and Europe. Most indicate that few respondents are familiar with the term nanotechnology and even fewer profess much, if any insight, regarding this technology (Cobb and Macoubrie, 2004; European Commission, 2001; Gaskell *et al., 2*005; Waldron *et al.*, 2006). However, in direct contrast to the longstanding concern regarding biotechnology, most studies further indicate that the public is generally optimistic,

although largely unsure of any specifics, about NT (Cobb and Macoubrie, 2005; European Commission, 2001; Gaskell, *et al.*, 2005; Waldron *et al.,* 2006). Likewise, 46% of Americans and 39% of Canadians agreed that nanotechnology 'will improve our quality of life over the next twenty years' with 57% of Americans and 64% of Canadians indicating they are 'not at all familiar' or 'not very familiar' with nanotechnology (Priest, 2003). This, in part, reflects the widely promoted and tangible consumer-focused benefits of NT, especially regarding human convenience and health, and in part the relatively intangible nature of NT-associated risks.

Controversies surrounding NT and other new technologies also reflect the processes underlying and the degree to which larger society has been involved in decision-making. The public is generally critical of self regulation by industry and some experts argue that any concerns would likely diminish if the communication of risks and benefits regarding food and health, which are most likely to emerge as controversies in the future, were more balanced and effective (Siegrist, 2007; Rejeski, 2006). Ongoing public consultation is increasingly recognized as important for reducing fear and controversy surrounding new technologies. This ideally occurs early in the process of development, and would arguably have helped to reduce perceived risks and negative attitudes towards biotechnology (Mehta, 2004; Priest, 2006). Yet few lessons have seemingly been learned by government and industry and there has been and continues to be little public input regarding NT (Mehta, 2004). Without meaningful and wide scale public consultation, it will be difficult to predict which NT applications are of concern and which are seen as meeting important societal needs on the part of decision-makers (Priest, 2006).

Indeed, a social learning approach would allow consumers to have greater and

more informed discretion regarding new technology and assessment, in part because these attitudes differ widely across nations and cultures (Cronin, 2004; Moon and Balasubramanian, 2004). Important social and cultural differences exist regarding new technologies, even between North America and Europe where most of the comparative studies have focused. The European public is generally less supportive and more cautious about biotechnology than nanotechnology (Gaskell *et al.*, 2005). These differences in attitude arguably reflect the emphasis on the *precautionary principle* (Appendix 1) by European Union regulators and the establishment of mandatory labelling for some foods contained GM ingredients (McCluskey, 2004). This regulatory approach is in strong contrast with the (science-based) emphasis of risk management in North America, and is arguably aggravated by the widespread food insecurity experienced throughout Europe during both World Wars as well as a greater distrust of governments and experts in Europe (Caplan, 2000; Gaskell, Eyck, Jackson, and Veltri, 2005).

Interestingly, research that compares consumer attitudes and behaviour toward GM foods in Asia, North America, and Europe emphasizes the importance of cultural attitudes because risk perceptions are increasingly seen as shaped by the social, cultural, and political context, contexts that clearly vary among nations (Macoubrie, 2006; McCluskey, 2004). Yet, few studies have shown how these attitudes shaped by differences in culture. The objectives of this study are to assess attitudes towards NT and to what degree they reflect underlying trust in science and governments, to contrast the attitudes of experts with those of the public, and to explore to what degree these attitudes are shaped by cultural differences between Canada and South Korea. These represent two countries that have made substantial investments in NT, yet they represent very different cultural and

historical contexts for these investments.

3. METHODS

3. 1. Study area

This research was conducted in Canada and South Korea (herein Korea). Sampling was located in the largest city and a second smaller city in each country: Toronto (i.e. the Greater Toronto Area) and Winnipeg in Canada and Seoul and Gwangju in Korea (Table 3.1).

Table 3.1 Characteristics of the four cities in Canada and South Korea where this study was conducted

Cities	Population	Area (km)	Features
Toronto*	5,113,149	5,903	Provincial capital of Ontario and largest city in Canada
Winnipeg	682,070	5,302	Provincial capital of Manitoba and eighth largest in Canada
Seoul	9,820,171	605	Capital of and the largest city in Korea
Gwangju	1.417,716	501	Provincial capital of South Jeolla Namdo and sixth largest city in Korea

* Greater Toronto Area
Source: Statistics Canada (2006) and Korea National Statistical Office (2005)

The total GDP (Gross Domestic Product) of Canada ranks eighth in the world ($1,271,593 million USD) whereas that of Korea is thirteenth ($888,024 million USD) (World Bank, 2007). Governments of both countries have designated Science and Technology (S&T) as a key priority and introduced a flexible research and development system of management (Maclurcan, 2006; TTC, 2007; Lee, 2002). In 2003, over $30 billion was invested in the NT industry worldwide, where it is seen as essential for a strong economic platform for the future. Both countries have also invested heavily in nanoscience and nanotechnology, this at comparable levels ($120 million in Canada from 2002 to 2006 vs. $154 million for Korea in 2002) (Waters, 2003). For all countries,

Canada ranked tenth (n=5,017) for publications on nanotechnology whereas Korea ranked ninth (n=6,679) from 1976 to 2004 (Li *et al.*, 2008).

3. 2. Data collection

This study design was mixed methodology in approach (Creswell, 2003) and was approved by the Joint-Faculty Human Subject Research Ethics Board Protocol at the University of Manitoba (#J2007:113).

A questionnaire was designed that assessed attitudes toward science and technology, the environmental, health and social implications of nanotechnology, and possible responses to any risks associated with NT. It consisted of seven-point Likert scaled and open-end questions. Twelve pages in length, it took 30-60 minutes to complete. The questionnaire was pre-tested with 10 students and five Canadian experts in nanotechnology from academy, non-governmental-organizations, government, and the nanoindustry, helping ensure that its content and wording were appropriate.

The survey was conducted from November 2007 until May 2008. In total, 975 questionnaires were completed: 513 in Canada and 462 in Korea. Sampling was stratified between students (n=488), the general public (n=398), and experts (n=89). Attempts were made to have an equal proportion of men and women represented as well as a broad range of ages, incomes, and education classes reflected in the sampling (Table 3.2). Interviews with the public were largely conducted in train stations and shopping malls as well as universities in all the cities. As a sign of appreciation for participating, all respondents were given a Korean bookmark ($3 USD value). Respondents were randomly recruited in the morning, afternoon, and evenings, in order to reflect a broad

sample of the population in each city.

In total, both undergraduate (n=252) and graduate (n=236) students were recruited in all four cities. These included the School of Earth and Environmental Sciences and the Department of Materials Science and Engineering at Seoul National University in Seoul, the Department of Earth Systems and Environmental Sciences and the College of Engineering at Chonnam National University in Gwangju, the Centre for Environment and the Division of Engineering Science at the University of Toronto in Toronto, and the Faculty of Environment, Earth, and Resources and the Faculty of Engineering at the University of Manitoba in Winnipeg.

Sampling was also stratified according to the flowing programs of study: engineering (n=301), environment (n=227), life sciences (n=95), and general arts and humanities (n=229). Subsequent interviews were conducted with experts, in person, by email, or by telephone, these also occurring from November, 2007 until May, 2008. In total, 89 experts participated from Canada (n=48) and Korea (n=41). The expert groups that were reflected included academia (n=65), non-governmental organizations (n=12), industry (n=7), and government (n=5). These included researchers working in various fields of nanotechnology, such as biomedical, electrical, computer, and materials sciences as well as physics, and chemistry. Moreover, it included researchers involved in nanotechnology in environmental fields including ecology, forestry, and geology. Additional experts (n=36) responded to a series of open ended questions that focused the most important benefits and risks associated with nanoproducts; ways in which to reduce and regulate any risks associated with nanomaterials or nanoproducts; and ways in which to respond to any public concerns regarding perceived risks.

3. 3. Data analysis

Overall there was much interest on the part of randomly selected participants, and, in general, 50% of students and 41% of the general public, and 9% of experts that examined the survey agreed to partake in the research. Reasons for not participating in the research included, in declining order of importance: lack of time, lack of interest in NT, lack of knowledge regarding NT, and lack of interest in this research as a whole.

Demographic data were directly reflected in questions included in the questionnaire. Specific disciplines of study that were recorded were assigned to five broader classes: none, general arts and humanities, environment science, life sciences, and engineering (Table 3.2). Socio-demographic variables were summarized and assessed for homogeneity of variance using ANOVA for equality of variance (SPSS version 16.0). Means and standard error were calculated for both dependent and independent variables. These were then compared between countries using two-tailed t-tests, and assessed as significant if $p < 0.0005$.

Independent variables that were later quantified included age, education, discipline, financial wellbeing, marriage status, gender, expertise of NT, and religion (Table 3.2 and 3.4). Additional independent variables were constructed by categorizing trust in science, in scientists, in technology, and in governments as well as concern regarding human health, social impacts, the environment, and public input (Table 3.4). In total, 16 independent variables were selected for use in further model building. Theses independents variables were first screened for multicollinearity using a Pearson rank correlation matrix for all possible pairs of independent variables (Burnham and Anderson; 2002). As no two variables had $r > 0.7$, all variables were retained for further

analysis. Surveys that had three or more missing responses to these questions were eliminated, resulting in a reduced sample size of 859.

Factor analysis (varimax rotation) was used to identify attitudes towards NT (Table 3.3). Any loading on a factor that was at least 0.400 was assigned to a factor. Alpha coefficients were calculated to test the reliability of the Likert scale for each factor and associated questions (Cronbach, 1951). All alpha values were >0.60 and were thus considered satisfactory for internal consistency of a scale and appropriate for variable reduction (Hatcher, 1994). Differences in means for factor scores were compared between the two countries and between experts and the public using two-tailed t-tests.

Regression analyses were conducted separately for Canadian and Korean samples (Table 3.5) and to compare public and expert responses for each country (Table 3.8). Expertise in NT was assessed according to responses to the question: "I am knowledgeable about Nanotechnology" which were measured with a seven-point scale. These Likert responses were then classed into three groups: low (1-2), medium (3-5) and high (6-7) (Table 3.4), and the medium class was then eliminated from subsequent analysis. These groups were calculated for experts and the public for both countries (Table 3.6, Table 3.7, and Table 3.8).

Qualitative data arising from open-ended questions in the survey were recorded, systematically evaluated and coded, and any emerging themes identified (Maxwell, 2005). These themes were then matched with quantitative outcomes. This mixed methods approach was used to both triangulate responses and to further elaborate upon and interpret the results.

4. RESULTS

4.1. Socio-demographic characteristics

In total, 513 people from Canada and 462 people from Korea participated in the research. Because interviews have been stratified according to age, education, and gender, there was much similarity in demographics between the two countries. Yet respondents in Canada tended to be older (12% vs. 8% over 46 years of age) and more likely to have graduated from university (75% vs. 63%) whereas those from Korea were more likely to have graduated from engineering programs (27% vs. 35%) and to have adequate financial resources (86% vs. 75%). More respondents from Korea were single (72% vs. 59%) (Table 3.2).

Table 3.2. Comparative demographics of survey respondents in Canada and South Korea

Variable	% Survey Respondents	
	Canada (n=513)	S. Korea (n=462)
Age (p=0.329)*		
18-30 (1)	64.9	66.0
31-45 (2)	19.1	24.5
46-60 (3)	10.1	6.9
61-over (4)	1.4	0.6
Education (p=0.031)*		
Less than high school (1)	1.4	0.4
High school graduate (2)	3.7	3.5
Some university (3)	17.5	31.6
University grad (4)	38.6	28.1
Postgraduate (5)	36.6	34.8
Discipline (p=0.001)*		
None (0)	16.2	8.7
Arts (1)	23.6	23.4
Environment (2)	23.2	23.4
Life Sciences (3)	9.7	9.7
Engineering (4)	27.3	34.8
Financial Wellbeing (p=0.622)*		
Not enough (1)	4.3	2.8
Tight (2)	15.6	8.7
No extra money (3)	30.0	48.3
Have extra money (4)	37.4	35.7
Enough (5)	7.4	2.4
Marriage Status (p=0.049)*		
Single (1)	59.4	71.9
Common-law (2)	8.6	0
Married (3)	23.0	25.5
Divorced (4)	1.9	0.2
Gender		
Female (0)	45.6	45.2
Male (1)	54.4	54.8

* Significant difference between the two countries for ANOVA (p<0.0005).

4.2. Perceptions towards science and technology

Generally speaking, most respondents in Canada and Korea (86% vs. 85%, respectively) were excited about the value of science for humanity (Table 3.4). They generally felt that technology was central for solving problems that face humans. These positive attitudes towards science and technology were reflected in attitudes regarding nanotechnology. Many respondents, especially in Korea (52% vs. 81%) at least somewhat agreed with the statement "NT will improve our daily life over the next 20 years" and most (72% vs. 76%) at least somewhat agreed that "government should promote research on NT" (Table 3.3).

"I think NT will continue to develop and have positive effects on society."
(#106, Korea)

Yet many respondents from both countries recognized they knew little (42% vs. 34%) or were neutral (34% vs. 50%) regarding their knowledge of NT, and only a minority (24% vs. 16%) saw themselves as knowledgeable (Table 3.4).

"Without having any knowledge of NT, I have taken this survey and done it while regretting my ignorance." (#283, Korea)

"I now realize that I have a very limited understanding and knowledge concerning NT." (#944, Canada)

Some indicated an interest in learning more about NT:

> *"I just have a little knowledge of NT but I am getting more interested in NT." (#341, Korea)*

While some were surprised about possible risks of NT, given even a little information on the survey questionnaire, they generally remained strongly supportive of NT.

> *"I had been always very appreciative of scientists when they announced NT and was cheering them with respect to their efforts and advancements. However, I am surprised by weakness of science, knowing the side effects from the survey." (#140, Korea)*

Others felt that this lack of information was inevitable in any emerging science:

> *"Every new science and technology includes potential threats, but the more technology has been developed, the more additional technology has been developed to reduce any risks. As a result, this fear is inevitable for any advance of all emerging technologies." (#867, Korea)*

Indeed, they felt that a focus on the negative implications would be counterproductive, especially if too general in nature:

> *"The public who only has access to negative information about NT may perceive*

that the technology would be bad. I think that all nanotechnology is not harmful so that we should need to discuss more about specifics regarding NT when informing the public." (#887, Korea)

These negative approaches would perpetuate these fears about this new technology.

"I am really not satisfied with the way nanoscience and nanotechnology are portrayed and hyped up to the general public. I am not surprised that people imagine such dark and menacing things would be potentially dangerous." (#919, Canada)

In contrast, others felt this lack of knowledge was, in part, related to the absence of balanced and adequate information surrounding NT.

"I only know about superficial, positive views of NT." (#336, Korea)

Thus, some respondents thought there should be an increase in risk-related research and adequate regulation, especially as the availability of nanoproducts grows.

"I think it would be worth to research potential societal threats while the development of nanotechnology continues to grow the need."(#869, Korea)

"There is important risk assessment that has to be done invariably for all [NT]

products."(#383, Canada)

Indeed, of those willing to use the technology, only a minority of respondents (12% vs. 17%) felt that "scientists have proven the safety of nanoproducts" (Table 3.3) and most (78% vs. 79%) thought that "the safety of each nanoproduct should be evaluated on a case-by case basis." Because of the uncertainty regarding the safety of nanotechnology, many respondents from both countries identified a variety of ways for reducing concern, many of the comments focusing on more effective public information and public participation:

"It would be good if informative books and materials are available for public with specific examples and information on nanotechnology." (#313, Korea)

"Teaching the public about the science and its limitations will turn this into more than a black and white debate. We need people to actually assess risks and to provide good, logical arguments."(#919, Canada)

Increases in information and thus insight into the technology might play a role in reducing both the worry regarding NT and the impasse between proponents and opponents.

"I believe in small, incremental improvements and benefits as opposed to sudden and radical changes. Public education is a key to removing some of the fear that many associate with the word "nano." (#919, Canada)

Others were concerned that this might result in too much information, regarding NT and the risks that society as a whole now has to contend with.

> *"The general public has to understand and make choices as to many risk sectors. The collective consciousness only has room for a limited amount of information."(#606, Canada)*

Ultimately, a substantial minority of respondents from both Canada and Korea (29% vs. 25%) were highly critical of NT. Many, especially from Korea (42% vs.66%) at least somewhat agreed with the statement that "industry will benefit more from NT than consumers." Others, especially in Korea, somewhat agreed that NT had the potential to make rich countries richer and poor countries even poorer (31% vs. 53%).

> *"I don't believe NT will be the savior to our myriad global problems that it is often touted as being. Rather than looking towards technology as the solution, it is time to begin confronting the root causes of those problems with pragmatism, compassion - and soon." (#609, Canada)*

> *"I wish the research on NT would be used to reduce the problems facing humanity and the environment. The nano-industry, in particular, should not focus only on economic priorities." (#311, Korea)*

In the absence of adequate research, some felt that the potential threats were great enough

that a precautionary approach to risk management should be adopted in the interim.

> *"With the many unknown risks related to NT, especially those related to potential ecological impacts, human health, animal health and even the potential impact on cultures, we need to utilize all precautionary tools available to us. (#609, Canada)*

4.3. Relative importance for nanoproduct categories

Respondents were asked to rank the relative importance of human convenience, environmental health, and human health for nanoproducts. Respondents from both countries ranked human health as most important and convenience as least important, although Canadians were more likely to identify human health as important and Koreans more likely to see the importance of consumer convenience (Figure 3.1).

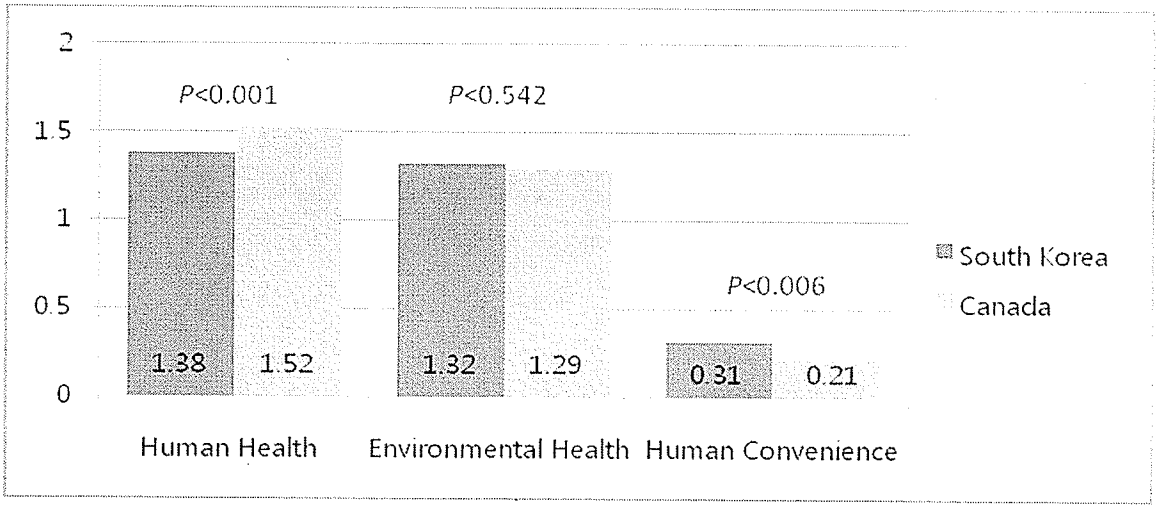

Figure 3.1. Relative importance of human health, environmental health, and human convenience for nanotechnology in Canada and South Korea. Scale ranges from "least important" (1) to "most important" (3). Corresponding means indicated at the base of each column.

Correspondingly, respondents from both countries more strongly supported products related to human health and environmental health than those related to human convenience (Figure 3.2). Respondents from both countries ranked early detection of cancer as being of the greatest benefit. Where precise drug delivery systems were ranked second in Korea, effective clean up of oils spills ranked second in Canada. Sensors for chemical toxins were ranked second in Korea and third in Canada. At the other extreme, highly effective sunscreens were ranked lowest in Korea and self-cleaning fabrics lowest in Canada.

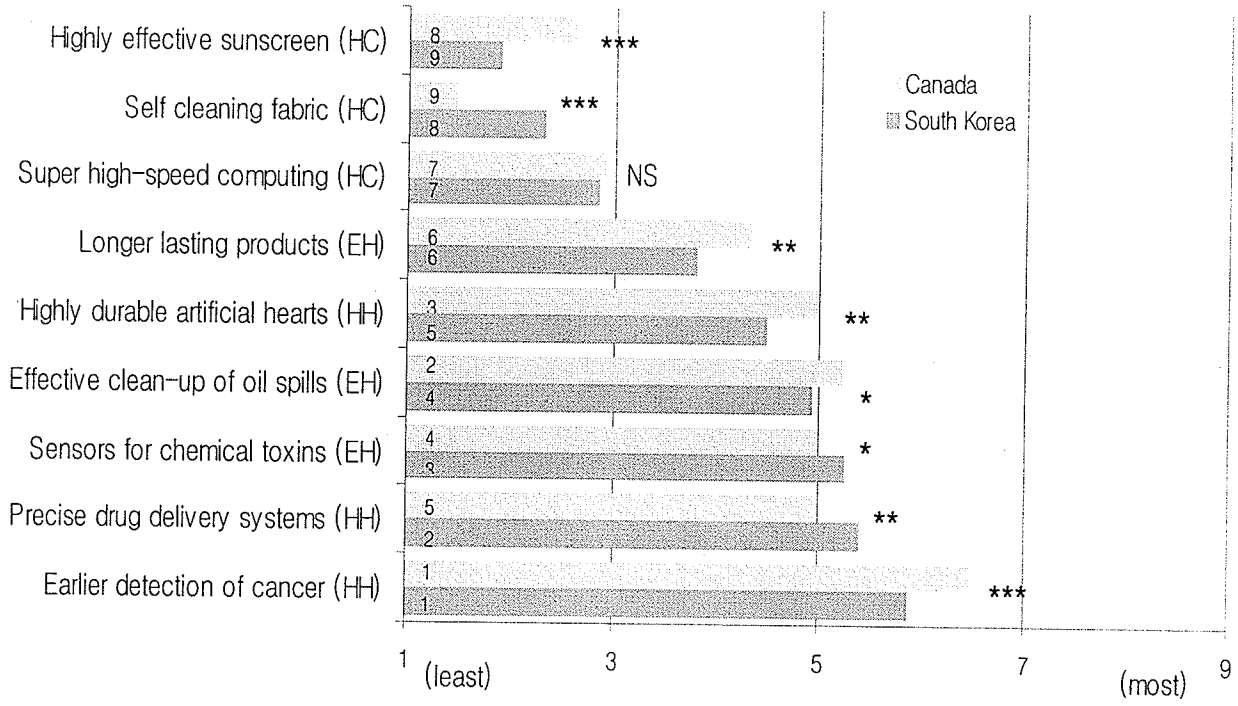

Figure 3.2. Relative importance of nine generalized nanoproducts from three categories uses (human health, environment, and convenience) in Canada and South Korea. HH: human health, EH: environmental health, HC: human convenience. Scale ranges from "least important" (1) to "most important" (9). *NS*: non significant, *$p< 0.05$, **$p< 0.005$, ***$p< 0.0005$.

Table 3.3. Definitions and descriptive statics of variables used in regression analysis between Canada and South Korea.

Var.	Statement[1]	Factor Loading			Canada (n=513)		S. Korea (n=462)		Sig.[5]
		Factor 1[2]	Factor 2[3]	Factor 3[4]	Mean (*SE*)	Alpha	Mean (*SE*)	Alpha	
O1	Industry will benefit more from NT than consumers.	**0.77**	0.14	0.01	5.53 (0.09)[1]	0.77	5.43 (0.07)	0.64	0.395
O2	If we enhance human capacities with NT, this will hurt those that now have disabilities.	**0.75**	-0.09	0.19	4.77(0.11)	0.78	4.25 (0.10)	0.65	**<0.0005**
O3	NT will make rich countries richer and poor countries poorer.	**0.74**	0.12	0.09	5.62 (0.09)	0.77	5.28 (0.08)	0.65	**0.007**
O4	Pace of NT development should slow down for more public input.	**0.71**	-0.16	0.08	4.83 (0.09)	0.80	4.15 (0.09)	0.65	**<0.0005**
U1	NT will improve our daily life over the next 20 years.	-0.01	**0.82**	0.07	5.25 (0.07)	0.79	5.85 (0.06)	0.63	**<0.0005**
U2	Government should promote research on nanotechnology.	-0.07	**0.80**	0.01	5.59 (0.06)	0.80	5.63 (0.06)	0.63	0.630
U3	Too much emphasis on the risks of NT will threaten the growth of this important industry.	-0.02	**0.56**	0.31	4.61 (0.08)	0.79	4.52 (0.07)	0.63	0.427
U4	NT will significantly accelerate medical progress.	0.35	**0.56**	0.21	5.95 (0.07)	0.77	5.90 (0.05)	0.63	0.618
C1	The economic benefits of NT outweigh any possible risks.	0.17	0.06	**0.85**	4.57 (0.11)	0.76	3.69 (0.08)	0.64	**<0.0005**
C2	Benefits of nanomedicines outweigh any risks.	0.19	0.10	**0.84**	5.00 (0.10)	0.76	4.18 (0.08)	0.63	**<0.0005**
C3	The benefits associated with NT outweigh any risks.	-0.03	0.45	**0.66**	6.20 (0.05)	0.77	5.89 (0.09)	0.62	**<0.0005**

Extraction method: Principal Component Analysis; Varimax rotation with Kaiser normalization.
[1]All scale ranges from "strongly disagree" (1) to "strongly agree" (7).
[2]Variables comprising the "opponents (O1-O4)" index.
[3]Variables comprising the "unconditional proponents (U1-U4)" index.
[4]Variables comprising the "conditional proponents (C1-C3)" index.
[5]Significant difference between means of the two countries as indicated by ANOVA

4.4. Differences in attitudes toward nanotechnology between Canada and South Korea

Three principal components were identified using factor analysis, the first accounting for 30 %, the second for 20%, and the third for 11% of the total 61% variance (Table 3.3). Values of Cronbach's alpha for the three factors were >0.60, ranging from 0.76 to 0.80 in Canada and from 0.62 to 0.65 in Korea. (Table 3.3).

Factor one grouped respondents as opponents to NT. Those opposed to the technology were likely to indicate that industry would be more likely to benefit than consumers (O1) and to hurt those that were less privileged (O2), including the disabled and those in poor countries (O3). Moreover, they felt that the pace of development should slow down to enable more public participation (O4). Although Canadian and Korean respondents were equally likely to view the nano-industry as the primary beneficiaries (5.53 vs. 5.43), with respect to all other concerns, opponents from Canada were significantly (p=0.007, p<0.0005) more likely to be critical of these issues than Koreans (Table 3.3).

Unconditional proponents of NT sorted out on factor two, and were more likely to assume that NT would improve their daily lives over the next 20 years (U1) and that it would accelerate medical progress (U4). They felt that governments should support the industry (U2), an industry that would be threatened if too much emphasis was placed on any attendant risks (U3) (Table 3.3). In general, there was no difference in these views between the two countries, although Koreans were significantly (p<0.0005) more likely to see an NT-associated increase in quality of life (Table 3.3). Finally, conditional proponents of NT sorted out onto factor three. They were likely to view the benefits as outweighing the risks, especially those that were economic and health oriented. In all

cases, Canadians were more likely to identify these benefits than their Korean counterparts.

Table 3.4. Differences in independent variables between Canada and South Korea used in regression analysis.

Variable	Description	Canada (n=513)		Korea (n=462)		Sig.[4]
		Mean (*SE*)	Alpha	Mean (*SE*)	Alpha	
Expertise of NT [1]	1. I am knowledgeable about nanotechnology. [2]	4.10 (0.07)	0.64	4.10 (0.09)	0.69	0.991
Religion [2]	1. I am a religious person.	3.86 (0.10)	0.66	3.63 (0.19)	0.70	**0.089**
Trust Government [2]	1. I trust government	3.52 (0.07)	0.64	3.29 (0.06)	0.69	**0.010**
Trust Science [3]	1. I am excited about the value of science for humanity. 2. Science is about truth.	11.31 (0.10)	0.62	11.05 (0.10)	0.67	**0.071**
Trust Scientist [3]	1. I trust scientists. 2. Scientists have proven the safety of nanoproducts.	7.79 (0.09)	0.64	8.13 (0.09)	0.69	**0.009**
Trust Technology [3]	1. I think technology is central to solving problems facing humanity in the future. 2. I am interested in nanotechnology	10.53 (0.10)	0.62	10.55 (0.10)	0.67	0.875
Concern in Health [3]	1. I worry about the effects of nanoproducts on my health. 2. The impacts of nanoproducts on human health are no different from non-nanoproducts.	8.05 (0.08)	0.63	7.92 (0.09)	0.70	0.296
Concern in Social Impact [3]	1. It is fine that profit rather than human need drives NT research. 2. If we enhance human capacities with NT, this will hurt those that now have disabilities.	7.25 (0.09)	0.64	8.09 (0.10)	0.69	**<0.0005**
Concern in Environment [3]	1. I am greatly concerned about threats to the environment. 2. NT will have substantial environmental risks.	10.32 (0.07)	0.64	10.32 (0.08)	0.69	0.993
Concern in Public Input [3]	1. The public should be meaningfully involved in decisions about new technology. 2. The public should participate in decision-making regarding NT.	10.38 (0.09)	0.61	10.34 (0.09)	0.65	0.747

[1]Scale ranges from "low" (1), middle (2) to "high" (3) which were measured with a eight-point scale (1=strongly disagree, 7=strongly agree, and 8=do not know) extracted ranges from 1-3 along with do not know for low, 4-5 for middle, and 6-7 for high.
[2]Scale ranges from "strongly disagree" (1) to "strongly agree" (7).
[3]Scale ranges from "strongly disagree" (2) to "strongly agree" (14).
[4]Significant difference between the two countries for ANOVA.

4.5. Comparison in attitudes between Canada and South Korea

In order to better understand the reasons underlying any differences in responses between Canada and Korea, separate factor analyses were conducted for each country. The linear multiple regression analyses were conducted for 16 independent variables (i.e. trust, concern, and demographics) using scores on each of the three factors as the dependent variable (Table 3.5).

Variables that significantly affected attitudes towards NT in Canada and Korea included concern over potential social impacts ($p<0.001$), the environment ($p<0.05$), human health ($p<0.0005$), and trust in technology ($p<0.05$), and knowledge of NT ($p<0.05$). Demographic variables that significantly influenced attitudes towards NT included gender ($p<0.01$), religion ($p<0.05$), education ($p<0.05$), and academic specialization ($p<0.05$).

Opponents (factor 1) of NT from both Canada and Korea were more likely to distrust scientists. Korean respondents were likely to be concerned about potential social and environmental impacts and to desire greater public participation in decision-making regarding NT. Those from Canada were likely to be female ($\beta = - 0.14$), were unlikely to be associated with the natural sciences and engineering ($\beta = - 0.11$), and were unlikely to be knowledgeable of NT ($\beta = - 0.24$) (Figure 3.3).

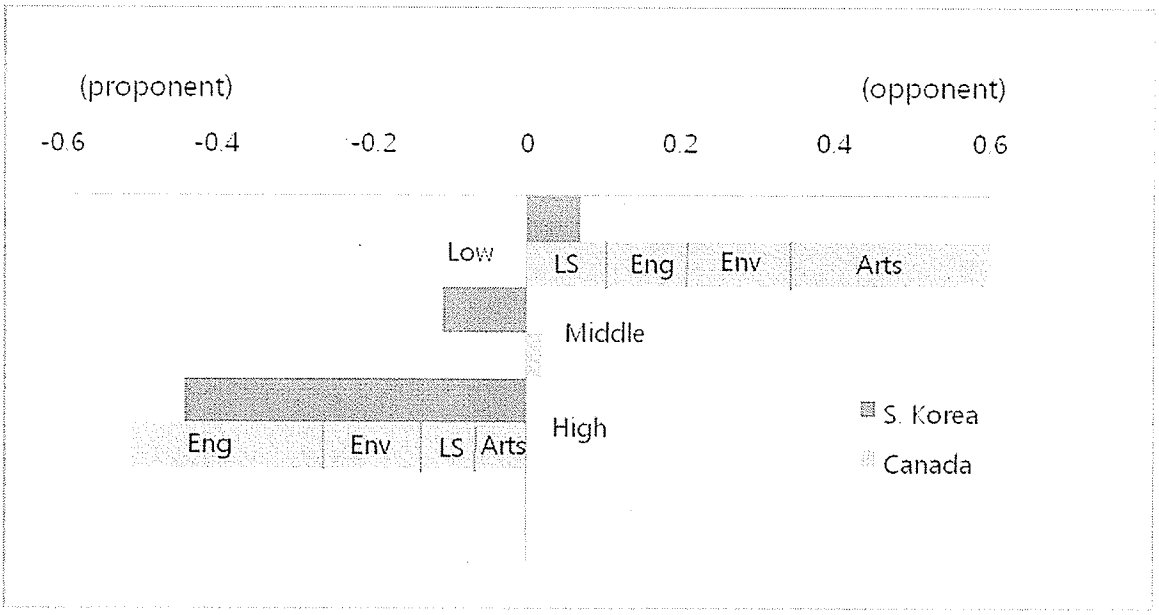

Figure 3.3. Effect of educational background on the degree to which respondents were opposed (factor 1) to NT for both Canada and South Korea. Results represent combined expertise and discipline in opponents (factor 1) on nanotechnology from both Canada and South Korea. Also indicated are the proportions of those associated with different formal academic backgrounds.

Unconditional proponents (factor 2) of NT from both Canada and Korea were likely to trust technology ($\beta = 0.26$, $\beta = 0.15$, respectively) and, in Korea, to support science ($\beta = 0.21$). They were unlikely to be concerned about social impacts of NT ($\beta = -0.17$, $\beta = -0.08$) and, in Canada, were unlikely to be concerned about the environment ($\beta = -0.13$). Those from Korea were unlikely to be religious ($\beta = -0.13$) (Table 3.5).

Conditional supporters (factor 3) ultimately weighed the benefits of NT as greater than any associated costs. Those from Korea were likely to trust scientists ($\beta = 0.17$) and were likely to be concerned about human health ($\beta = 0.20$). In contrast, they, along with their Canadian counterparts, and with unconditional supporters, were unlikely to be concerned about any impacts on the environment ($\beta = -0.21$, $\beta = -0.02$). Canadian conditional proponents were likely to be female ($\beta = -0.12$) and to be religious ($\beta = 0.15$)

whereas those from Korea were at once less formally educated (β = - 0.12) and were likely to be knowledgeable about NT (β = 0.12) (Table 3.5 and Figure 3.4).

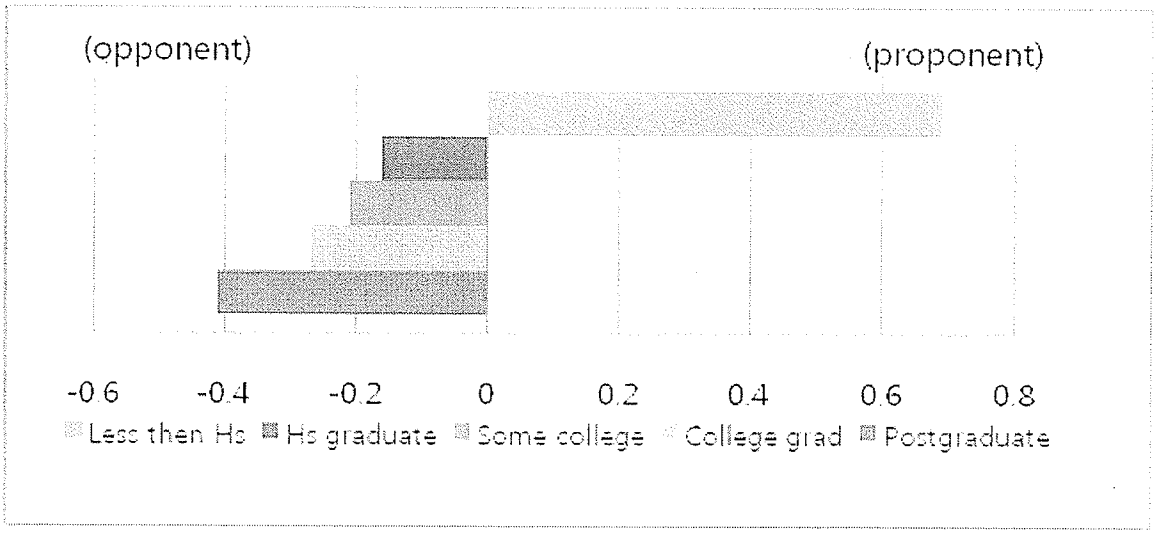

Figure 3.4. Effect of education for conditional proponents (factor 3) of nanotechnology in only South Korea. Units on x-axis reflect factor scores.

Table 3.5. Summary of multiple regression analysis on three factors (opponents, proponents, conditional proponents) with independent variables in Canada and South Korea.

Predictor[1]	Factor 1 (OPPONENTS)		Factor 2 (PROPONENTS)		Factor 3 (CONDITIONAL PROPONENTS)	
	Canada	S. Korea	Canada	S. Korea	Canada	S. Korea
	Beta t-value	Beta t-value	Beta t-value	Beta t-value	Beta t-value	Beta t-value
Trust						
Science	*NS*[2]	*NS*	*NS*	0.21 3.03(**)	*NS*	*NS*
Scientist	-0.13 -2.49(*)	-0.12 -2.28(*)	*NS*	*NS*	*NS*	0.17 3.01(**)
Technology	*NS*	*NS*	0.26 4.23(***)	0.15 2.64(*)	*NS*	*NS*
Government	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Concern						
Health	*NS*	*NS*	*NS*	*NS*	*NS*	0.20 4.15(***)
Social Impact	0.14 3.04(**)	0.23 4.92(***)	-0.17 -3.31(**)	-0.08 -1.72(**)	*NS*	*NS*
Environment	*NS*	0.12 2.50(*)	-0.13 -2.54(*)	*NS*	-0.21 -3.97(***)	-0.02 3.30(**)
Public Input	0.16 2.75(*)	0.20 3.44(**)	NS	*NS*	*NS*	*NS*
Demographics						
Gender	-0.14 -0.05(**)	*NS*	*NS*	*NS*	-0.12 -2.44(*)	*NS*
Age	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Education	*NS*	*NS*	*NS*	*NS*	*NS*	-0.12 -2.32(*)
Discipline	-0.11 -2.21(*)	*NS*	*NS*	*NS*	*NS*	*NS*
Finance	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Marriage Status	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Expertise of NT	-0.24 -4.64(***)	-0.14 -2.70(*)	*NS*	*NS*	*NS*	0.12 2.21(*)
Religion	*NS*	*NS*	*NS*	-0.10 -2.16(*)	0.15 3.04(**)	*NS*
F	11.08	7.31	5.62	6.53	3.83	4.13
***R2* (adjusted)**	0.30	0.22	0.18	0.20	0.13	0.14
N	513	462	513	462	513	462

[1] Coding used for dependent variables indicated in Table 3.1 and 3.3.
[2] *NS*: non-significant and significant at *$p < 0.05$; ** $p < 0.001$; *** $p < 0.0005$.

Table 3.6. Result of descriptive statics of variables used in regression analysis between the public and experts from Canada and South Korea

Var.[1]	Canada (n=513)				Sig.[2]	S. Korea (n=462)				Sig.[3]	Sig.[4]	Sig.[5]
	Public (n=149)		Expert (n=123)			Public (n=80)		Expert (n=74)				
	Mean (*SE*)	Alpha	Mean (*SE*)	Alpha		Mean (*SE*)	Alpha	Mean (*SE*)	Alpha			
O1	6.31 (0.14)	0.68	4.72 (0.18)	0.51	**<0.0005**	5.82 (0.17)	0.76	5.23 (0.18)	0.46	0.018	0.037	0.055
O2	5.70 (0.21)	0.68	3.56 (0.20)	0.53	**<0.0005**	4.69 (0.26)	0.76	3.27 (0.20)	0.48	**<0.0005**	**0.003**	0.336
O3	6.06 (0.17)	0.67	4.97 (0.19)	0.51	**<0.0005**	5.48 (0.22)	0.76	4.86 (0.21)	0.43	0.048	0.041	0.723
O4	5.60 (0.14)	0.71	3.74 (0.17)	0.58	**<0.0005**	4.76 (0.24)	0.76	3.46 (0.21)	0.44	**<0.0005**	**0.002**	0.309
U1	5.17 (0.15)	0.74	5.70 (0.11)	0.58	**0.008**	5.96 (0.16)	0.75	6.41 (0.10)	0.42	0.594	**0.001**	**<0.0005**
U2	5.43 (0.12)	0.74	6.17 (0.10)	0.58	**<0.0005**	5.51 (0.17)	0.76	6.20 (0.11)	0.41	0.591	0.696	0.829
U3	4.68 (0.17)	0.78	4.96 (0.14)	0.60	0.204	4.79 (0.21)	0.76	4.82 (0.20)	0.40	0.632	0.685	0.565
U4	6.30 (0.13)	0.76	5.92 (0.10)	0.55	0.025	5.89 (0.15)	0.75	6.24 (0.11)	0.46	0.059	0.047	0.040
C1	5.01 (0.23)	0.69	4.30 (0.19)	0.50	0.022	3.80 (0.24)	0.77	4.05 (0.22)	0.46	0.437	**0.001**	0.408
C2	5.41 (0.21)	0.65	4.68 (0.18)	0.49	0.010	4.05 (0.24)	0.74	4.62 (0.20)	0.41	0.069	**<0.0005**	0.824
C3	5.27 (0.19)	0.66	4.98 (0.15)	0.64	0.253	4.50 (0.27)	0.75	4.72 (0.21)	0.31	0.527	0.018	0.296

Coding used for independent variables indicated in Table 3.2.

[1]O1-O4 (opponents), U1-U4 (unconditional proponents), C1-C3 (conditional proponents)

[2] Significant difference between Canadian public and experts for ANOVA.

[3] Significant difference between Korean public and experts for ANOVA .

[4] Significant difference between Canadian public and Korean public for ANOVA.

[5]Significant difference between Canadian experts and Korean experts for ANOVA .

Table. 3.7. Percentage of respondents responding positively and negatively to questions associated with the three factors underlying attitudes toward nanotechnology and used in regression analysis between public and expert in Canada and South Korea

Var.[1]	Canada				S. Korea			
	% Public (n=149)		% Expert (n=123)		% Public (n=80)		% Expert (n=74)	
	+ /-	Neutral/ DK[2]	+ /-	Neutral/ DK[2]	+ /-	Neutral/ DK[2]	+ /-	Neutral/ DK.[2]
O1	**37.1/ 4.9**	16.8/ 41.3	**39.8/ 27.6**	19.5/ 13.0	**62.5/ 6.2**	13.8/ 17.5	**68.9/ 14.9**	10.8/ 5.4
O2	**7.0/ 22.4**	20.3/ 50.3	**11.5/ 56.1**	20.3/ 12.2	**23.8/ 35.0**	17.5/ 23.8	**13.6/ 64.9**	17.6/ 1.4
O3	27.8/ 9.0	19.4/ 43.8	33.3/ 23.6	24.4/ 18.7	38.8/ 16.2	18.8/ 26.2	56.8/ 21.6	16.2/ 5.4
O4	**51.7/ 10.7**	16.8/ 20.8	**26.9/ 47.2**	21.1/ 4.9	**27.5/ 32.5**	21.2/ 18.8	**23.0/ 62.2**	12.2/ 2.7
U1	**29.2/ 10.2**	38.8/ 21.8	**82.7/ 4.1**	10.7/ 2.5	**63.7/ 3.8**	8.8/ 23.8	**94.6/ 1.4**	1.4/ 2.7
U2	55.4/ 4.7	28.4/ 11.5	89.5/ 0.8	8.1/ 1.6	51.5/ 2.5	27.8/ 17.7	94.5/ 1.4	2.7/ 1.4
U3	25.1/ 25.0	31.1/ 18.9	66.6/ 13.0	18.7/ 1.6	38.8/ 21.2	25.0/ 15.0	63.5/ 23.0	10.8/ 2.7
U4	42.1/ 0.7	16.6/ 40.7	86.1/ 2.4	4.9/ 6.5	60.8/ 3.8	12.5/ 15.0	93.3/ 2.7	2.7/ 1.4
C1	**6.9/ 35.9**	15.2/ 42.1	**28.5/ 38.2**	20.3/ 13.0	**27.5/ 55**	10/ 7.5	**91.9/ 2.7**	5.4/ 0
C2	6.3/ 28.5	20.8/ 44.4	32.5/ 27.6	25.2/ 9.8	20/ 45	21.2/ 13.8	40.1/ 27.0	21.6/ 1.4
C3	11.8/ 17.9	35.2/ 35.2	44.7/ 16.3	29.3/ 9.8	23.8/ 31.2	23.8/ 21.2	40.1/ 25.7	20.3/ 4.1

Coding used for independent variables indicated in Table 3.2.

[1]O1-O4 (opponents), U1-U4 (unconditional proponents), C1-C3 (conditional proponents)

[2]DK: *Do not know*

4.6. Public and expert perceptions in Canada and South Korea

Differences in attitude between experts and the public from Canada and Korea were substantial. Experts were less likely to indicate neutral attitudes or an inability to answer questions than the public (Table 3.7). The Canadian public had responses with higher mean values than any of the other three groups (i.e. Canadian experts, the Korean public, and Korean experts), and along with Canadian experts were more likely to indicate neutral or unknowing responses than their Korean counterparts (Table 3.6). Overall, the public from Canada was significantly ($p<0.0005$) more likely to oppose NT (factor 1: O1-O4). Experts from both countries were generally strong proponents of NT (81% in Canada vs. 87% in Korea) (factor 2: U1-U4) while the public were more likely to be neutral or not to know (53% in Canada vs. 39% in Korea) (Table 3.6 and Table 3.7).

Public respondents from Canada and Korea were more likely to be strong opponents of NT than any experts, especially regarding social impacts on the disabled (5.70 vs. 4.69, $p<0.0005$) as well as wanting to resist and slow down the pace of development to allow for more public participation (5.60 vs. 4.76, $p<0.0005$). The public was more likely to agree (6.31 vs. 5.82, $p<0.037$) that the industry would benefit more than consumers (O1) in Canada (37% + vs. 5% -) and in Korea (63% + vs. 6% -) in contrast to experts, especially in Canada (40% + vs. 28% -) (Table 3.6 and Table 3.7).

Moreover, the public and experts from Canada were more likely to differ significantly ($p<0.0005$) in their responses (i.e. O1-O4, U1-U2) except U3 and C3. Likewise, the public in Korea was most likely to differ in their responses compared to Korean experts, with respect to public and expert from Korea were highly significant ($p<0.0005$) to O2 (4.69 vs. 3.27, $p<0.0005$) and O4 (4.76 vs. 3.46, $p<0.0005$). Although the public from

both countries was highly supportive (42% vs. 61%, $p<0.047$) that "NT will significantly accelerate medical progress (U4)", they were at least somewhat negative (29% vs. 45%, $p<0.0005$) that "benefits of nanomedicines outweigh any risks (C2)" because of the unknown risks (65% vs. 34%). Likewise, experts from Canada were much more likely to agree (4.30 vs. 4.05, $p<0.04$) that economic benefits of NT would outweigh risks (C1) in Canada (29% + vs. 38% -) and especially Korea (92% + vs. 3% -) than were the public in Canada (7% + vs. 36% -) and in Korea (28% + vs. 55% -). The public was much more likely to agree (5.60 vs. 4.76, $p<0.002$) that there should be involvement in decision-making regarding NT (O4) in Canada (52% + vs. 10% -) and Korea (28% vs. 33%) than were experts (3.74 vs. 3.46, $p<0.309$) from Canada (27% + vs. 47% -) and Korea (23% + vs. 62% -) (Table 3.6 and Table 3.7).

Regression analyses were used to better understand reasons underlying differences in attitude between experts and the public for Canada and Korea (Table 3.8). The most important variables affecting expert and public attitudes towards NT included trust in scientists and technology ($p<0.05$), trust in science ($p<0.05$), concern over social impacts ($p<0.001$), the environment ($p<0.1$), and human health ($p<0.1$), and attitudes towards public input ($p<0.05$). Demographic variables that were also important included academic specialization ($p<0.001$), gender ($p<0.05$), and marriage status ($p<0.1$) as well as age ($p<0.05$), education ($p<0.05$), financial status ($p<0.05$), and religion ($p<0.05$).

Canadian experts who were opponents (factor 1) of NT were slightly more likely to be concerned about social impacts in Canada ($\beta = 0.45$) than Korea ($\beta = 0.41$) whereas those from Korea were distrustful of scientists ($\beta = - 0.29$) and were concerned about the environment ($\beta = 0.30$). Conversely, the Korean public who were opponents of NT

trusted science (β = 0.39) but distrusted scientists (β = - 0.34) whereas the Canadian public distrusted technology (β = - 0.27) and desired greater participation in decision-making regarding NT (β = 0.32). They, unlike the Korean public, were unconcerned about social impacts (β = - 0.19 vs. 0.28) and were likely to be better educated (β = 0.24), single (β = - 0.17), and older (β = 0.19). The public from Canada was likely to be religious, unlike Korea (β = 0.14 vs. - 0.19) and the public from both countries were likely to be female (β = - 0.16 vs. - 0.20) (Fig 3.5).

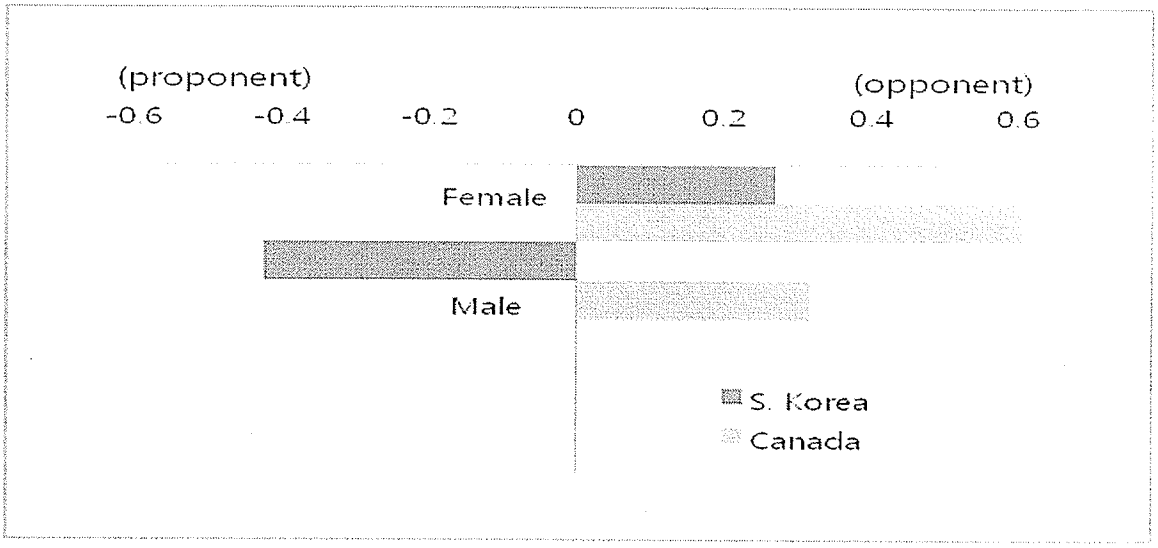

Figure 3.5. Effects of gender on opposing attitudes (factor 1) regarding nanotechnology for both Canada and South Korea. Units on x-axis reflect factor scores.

Implications of independent variables on the attitudes of those that were proponents of NT (factor 2) were also examined. Expert proponents from Canada had greater trust in science (β = 0.25), scientists (β = 0.23), and technology (β = 0.33), whereas those from Korea trusted technology (β = 0.55) and government (β = 0.25) and were less supportive of public input (β = - 0.23). Expert proponents from Canada were younger (β = - 0.18)

and religious (β = 0.22) whereas those from Korea were less well off (β = - 0.27) and were likely to be married (β = 0.34). Meanwhile, public proponents from Canada also trusted technology (β = 0.21) and had less concern about the environment (β = - 0.17) whereas the Korean public trusted science (β = 0.36), and was older (β = 0.33) and female (β = - 0.21) (Table 3.8).

When conditional proponents were examined, experts from Canada and Korea were unlikely to be concerned about the potential environmental risks of NT (β = - 0.20, β = - 0.28). Those from Canada were likely to be trained in the social sciences and humanities (β = - 0.21), whereas those from Korea were likely to trust scientists (β = 0.44) and to be older (β = 0.43). When public conditional attitudes were examined, respondents from Canada and Korea were both likely to trust scientists (β = 0.25, β = 0.44) and to distrust technology (β = - 0.26, β = - 0.28). Those from Canada were unlikely to be concerned about social impacts (β = - 0.25), were likely to be male (β = - 0.22), and were likely to be religious (β = 0.16). Public respondents from Korea were unlikely to trust science (β = - 0.31) but likely to be concerned about potential health impacts (β = 0.28), to be young (β = - 0.55), to be married (β = 0.61), and to be trained in the social sciences and humanities (β = - 0.39) (Table 3.8).

Table 3.8. Summary of multiple regression analysis on three factors with independent variables for both expert and the several public in Canada and South Korea

Predictor + Factor	Canada		South Korea	
	Public (n=124)	Expert (n=104)	Public (n=76)	Expert (n=66)
	Beta t-value	Beta t-value	Beta t-value	Beta t-value
FACTOR 1:Opponents				
Trust Science	*NS*[1]	*NS*	0.39 2.19 (*)	*NS*
Trust Scientist	*NS*	*NS*	-0.34 -2.72 (**)	-0.29 -2.27 (*)
Trust Technology	-0.27 -2.52 (**)	*NS*	*NS*	*NS*
Trust Government	*NS*	*NS*	*NS*	*NS*
Concern in Health	*NS*	*NS*	*NS*	*NS*
Concern in Social Impact	-0.19 -2.16 (*)	0.45 4.82 (***)	0.28 2.17 (*)	0.41 3.76 (***)
Concern in Environment	*NS*	*NS*	*NS*	0.30 2.45 (**)
Concern in Public Input	0.32 2.17 (**)	*NS*	*NS*	*NS*
Gender	-0.16 -2.20 (†)	*NS*	-0.20 -1.81(†)	*NS*
Age	0.19 1.97 (*)	0.21 2.09 (*)	0.34 1.93 (†)	-0.31 -1.67 (†)
Education	0.24 2.38 (*)	*NS*	*NS*	*NS*
Discipline	*-NS*	*NS*	*NS*	*NS*
Finance	*NS*	*NS*	*NS*	*NS*
Marriage Status	-0.17 -1.85 (†)	*NS*	*NS*	*NS*
Religion	0.14 1.68 (†)	*NS*	-0.19 -1.71 (†)	*NS*
FACTOR 2: Proponents				
Trust Science	*NS*	0.25 2.20 (*)	0.36 1.82(†)	*NS*
Trust Scientist	*NS*	0.23 2.38 (*)	*NS*	*NS*
Trust Technology	0.21 1.70 (†)	0.33 3.54 (**)	*NS*	0.55 3.01 (*)
Trust Government	*NS*	*NS*	*NS*	0.25 1.90 (†)
Concern in Health	*NS*	*NS*	*NS*	*NS*
Concern in Social Impact	*NS*	-0.16 -1.64(†)	*NS*	*NS*
Concern in Environment	-0.17 -1.69 (†)	*NS*	*NS*	*NS*
Concern in Public Input	*NS*	-0.23 -2.17 (*)	*NS*	*NS*
Gender	*NS*	*NS*	-0.21 -1.69 (*)	*NS*
Age	*NS*	-0.18 -1.71(†)	0.33 1.78 (†)	*NS*
Education	*NS*	*NS*	*NS*	*NS*
Discipline	*NS*	*NS*	*NS*	*NS*
Finance	*NS*	*NS*	*NS*	-0.27 -2.37 (*)
Marriage Status	*NS*	*NS*	*NS*	0.34 1.81 (†)
Religion	*NS*	0.22 2.49 (*)	*NS*	*NS*
FACTOR 3: Conditional Proponents				
Trust Science	*NS*	*NS*	-0.31 -1.79 (†)	*NS*
Trust Scientist	0.25 2.38 (*)	*NS*	0.44 3.52 (**)	0.44 2.76 (*)
Trust Technology	-0.26 -2.32 (*)	*NS*	-0.28 -2.24 (*)	*NS*
Trust Government	*NS*	*NS*	*NS*	*NS*
Concern in Health	*NS*	*NS*	0.28 2.25 (*)	*NS*
Concern in Social Impact	-0.25 -2.72 (**)	*NS*	*NS*	*NS*
Concern in Environment	*NS*	-0.20 -1.55 (†)	*NS*	-0.28 -1.86 (†)
Concern in Public Input	*NS*	*NS*	*NS*	*NS*
Gender	-0.22 -2.49 (**)	*NS*	*NS*	*NS*
Age	*NS*	*NS*	-0.55 -3.13 (*)	0.43 1.89 (†)
Education	*NS*	*NS*	*NS*	*NS*
Discipline	*NS*	-0.21 -1.79 (†)	-0.39 -3.60 (**)	*NS*
Finance	*NS*	*NS*	*NS*	*NS*
Marriage Status	*NS*	*NS*	0.61 3.63 (**)	*NS*
Religion	0.16 1.94 (*)	*NS*	*NS*	*NS*

Coding used for dependent variables indicated in Table 3.1 and 3.3.

[1]*NS*: non-significant and significant at †$p < 0.1$; *$p < 0.05$; ** $p < 0.001$; *** $p < 0.0005$.

4.7. Expert responses to possible benefits and risks of NT

Of those experts from Canada and Korea who responded to open-end questions regarding benefits associated with nano-products, most focused on the benefits for human health (33%), more effective medical treatment (17%), and new properties of medicines (5%). The major identified risks included harmful impacts on human health (32%), uncertainty of reliability (20%), and the accumulation of nanomaterials in the human body (18%) (Table 3.9). Advances regarding human health were most commonly identified as benefits (56%).

> *"Major benefits would be new materials and hyper-reliable technologies, as well as medical feats and miracle repairs of organs and "better" organs etc." (#929, Canada)*

> *"It is possible to benefit human health and life by novel function of the new products and new technology that are used by nanotechnology." (#873, Korea)*

Consumer convenience was ranked second (30%) especially regarding increased utility, affordability, quality, and cost.

> *"NT has higher utility, and better cost and function, which could result in excellent products that outperform conventional ones." (#888, Korea)*

> *"...more complex ("smarter") drugs, materials, devices with less cost to build." (# 892, Canada)*

Benefits for the environment were ranked lowest (14%) and highlighted increased energy efficiency and mitigation of stressors including global warming.

> *"Electronic automobiles that get energy from the sun or hydrogen fuel-cell cars, and light and strong cars that use carbon nano tubes. The resulting reductions in weight of cars should save oil and protect against global warming." (#856, Korea)*

> *"...possibility of sensing systems which can increase efficiency and save materials." (#881, Korea)*

In contrast, a wide range of possible risks regarding human health (70%) associated with nano-products were most commonly identified.

> *"It is possible that nanomaterials for protecting skin can be absorbed, not only to the layer of skin, but also into human body."(#869, Korea)*

> *"The invisible pollution they can create, the sicknesses that can be provoked by molecules accumulating in various parts of the body. Possible DNA disruptions on the genome of plants, humans, animals." (#929, Canada)*

Many environmental risks (23%) were also highlighted.

"There would be risk where materials and particles which do not decompose are accumulated in the human body and environment." (#850, Korea)

"Even the same materials can change toxicity at the nano level so that humans and environment could be harmed."(#861, Korea)

Possible risks surrounding consumer convenience were ranked lower (8%), and generally focused on social inequity and problems of product durability.

"Disparity between those having benefit of the technology and those not having it." (Government-#863, Korea)

"At most, it is very tiny in size and is highly efficient for its size. For these limitations, I think there would be problems of durability for these products." (Academy-#970, Korea)

Table 3. 9. Summary of major possible benefits and risks associated with nanoproducts from expert groups in Canada and South Korea from responses to open ended questions

Possible Benefits
Health (56%) 1) Effect on human health (33%) 2) More effective medicines on penetration and fast absorption (17.4%) 3) Excellent manufacturing of physical and chemical property such as, durability, elasticity, flexibility, lightweight, and strengthen (5.2%) **Convenience (30%)** 1) New utility, function, cost (15.8%) 2) Better quality than conventional products (14.2%) **Environment (14%)** 1) Effect on environment (10.5%) 2) Reduction of energy and resources usages, and protection of global warming (3.5%)
Possible Risks
Health (70%) 1) Harmful impacts especially for the respiratory system and gastrointestinal tract, and distribution through vascular, liver, organ, and nerve. (32%) 2) Low prediction and experiments on new functions, material transformation, and potential disease because of hard to recognize it when discharging it from the body and hard to get rid of it when attaching (20%) 3) Nanomaterials accumulated in body (18%) **Environment (22.5%)** 1) Materials and particles that accumulate or do not decompose (17.5%) 2) Changes chemical and physical properties of nanomaterials (5%) **Convenience (7.5%)** 1) Social impacts, especially, disparity between haves and have-nots (5%) 2) Unanticipated risks because of inferior products including reduced durability (2.5%)

4.8. Expert responses to reduce public fears about nanotechnology

Experts from both Canada and Korea indicated that there should be an increase in risk-related research and that this would help mitigate public fears about the new technology.

> *"It is possible to make a big issue about the risks associated with NT so that it is necessary to take notice and to conduct research because of an absence of information regarding these potential risks" (#888, Korea)*

Others, on the other hand, disagreed that public concerns were warranted.

> *"There are no meaningful concerns because there is no evidence regarding any potential risks. People do not need to worry about the risk of NT because industry and researchers have continuously worked to improve the technology." (#871, Korea)*

Some experts felt public concerns reflected an absence of adequate information on NT.

> *"Those who do not know would only be afraid of it."(#885, Korea)*

Yet many others recognized that informing the public would help reduce consumer concerns. Many wanted more detailed and accessible information on any health risks.

> *"When NT gradually comes into contact with human life, the issues should be*

addressed and brought to attention."(#919, Canada)

"Nanoparicles are absorbed by human body without discharging and would be potentially harmful we need to specify risks of NT and then inform the public." (#887, Korea)

It was recognized by some that information regarding potential benefits and risks should be balanced if it was to be seen as credible.

"For communicating the outcomes of research to the public, it should be emphasized to not only provide the fantastic benefits of nanotechnology but also indicate any limitations and potential risks regarding the technology." (#883, Korea)

Yet respondents were divided. Just over half of the experts (54% vs. 56% in Canada and Korea, respectively) at somewhat agreed with public participation in decision-making regarding NT, whereas a substantial minority at least somewhat disagreed (31% vs. 23%) (Table 3.4). However, most expert respondents agreed on the importance of regulation, and a majority in both countries at least somewhat agreed (67% vs. 73%) that "government should regulate risks associate with nanoproducts."

"Because of possibility of human health and environmental risks by microelements, regulations need to be created that can limit these risks." (#886, Korea)

5. DISCUSSION

This chapter characterized public and expert attitudes toward NT and more generally towards science and technology, contrasting attitudes of public and experts respondents from Canada and from South Korea. Other studies (e.g. Macoubrie, 2005; Tesh, 2000; Douglas, 1985; Short, 1984) have emphasized how to reduce public fear regarding emerging technologies. This research, by contrast, assessed public and expert attitudes to science and technology. Further, it linked attitudes towards NT to those regarding all emerging technologies, trust in science, governments, the nano-industry, the demographics of respondents, and the socio-cultural characteristics of both countries.

Understanding of Emerging Technology

Overall, most respondents from Canada and especially Korea had heard (84% vs. 94%) of NT, but relatively few (24% vs. 16%) indicated they were knowledgeable. This lack of familiarity on NT has been shown in many other studies (e.g. Cobb and Macoubrie, 2004; European Commission, 2001; Gaskell *et al., 2005*; Waldron *et al.*, 2006). Respondents to open-end questions indicated there was a lack of information and ineffective communication between experts and the public. These outcomes likely reflect the knowledge gap regarding NT that exists among respondents, a gap that differed between the two countries. Respondents with little knowledge were more common in Canada (42% vs. 34%) whereas those that were somewhat knowledgeable were more common in Korea (34% vs. 50%). Yet, this lack of knowledge not withstanding in both countries, there was a remarkable optimism regarding the technology. Thus, most respondents, especially in Korea (52% vs. 81%), at least somewhat agreed that NT would

improve the quality of their lives over the next 20 years. This optimism is also reflected in many other studies, especially those conducted in North America (Cobb and Macoubrie, 2005; European Commission, 2001; Gaskell, *et al.*, 2005; Waldron *et al.*, 2006). Yet, this widespread optimism varied substantially among respondents. As with other studies (e.g. Slimak and Dietz, 2006), there was a positive relationship between formal education and optimism regarding NT.

Indeed, respondents specializing in engineering and being relatively more knowledgeable of NT were generally also more supportive of NT. This at once reflects the lack of knowledge of the broader public and our difficulty in finding experts associated with organizations that were critical of the industry and of releasing nanoproducts on the market. Likewise, most experts researching NT in these countries would receive funding from industry and government that are proponents of NT. It can thus be argued that they would have livelihoods that were, to some degree at least, dependent upon this continued funding, and would thus be less likely to be critical of the technology.

Many studies have found that men and women vary substantially in the way they perceive risk (e.g. Boholm, 1998; Byrnes *et al.*, 1996; Miller and Schafer, 1999). Gender differences in relation to trust are significant (Finucane *et al.*, 2000) and women and people of European descent are generally less sensitive to technology-related risk than Afro-Americans (Oltedal *et al.,* 2004). In this study, opponents to NT from Canada (factor 1) were more likely to be women and were less likely to be knowledgeable of NT, and, for the public, less likely to have high levels of formal education. Indeed, the public that was male was less likely to be critical than their female counterparts, this reflected in

both countries. The importance of gender in influencing attitudes towards NT has been shown in other studies (e.g. Rejeski, 2006; Slimak and Dietz, 2006). Accepted at face value, these results suggest that educational outreach regarding NT might explicitly target women. Likewise, women and visible minorities often have less access to scientific information about risk than men (Kahan *et al.,* 2007). Other studies on NT show that men are less likely to perceive any risks (Rejeski, 2006; Slimak and Dietz, 2006). In Canada, respondents that were female, that had lower education or income, and that were residents of Quebec had heightened perceptions of environmental, therapeutic, and health risks (Lemyre *et al.,* 2006). Yet, these factors may also be indirectly reflected when speaking about high levels of expertise in NT. Experts in NT from Canada and Korea that generally had more favorable attitudes towards NT were also more likely to be men and were more likely to be trained in the sciences, especially engineering. It is now widely recognized that the proportion of women in the engineering and life sciences, this already low at the undergraduate level, declines even further at post-graduate levels.

The main benefits and risks associated with NT in this study were categorized into three classes: human health, environment, and human convenience. Generally, respondents were most excited about the potential of NT for human health. This was especially true for Canada (1.52 vs. 1.38, $p<0.001$). I had anticipated that human convenience would be ranked next highest; however, environmental benefits were ranked higher by respondents from both countries (1.29 vs. 1.32, $p<0.005$). Most respondents seemed to have little knowledge regarding specific nanoproducts that are already available on the market, in part reflecting the absence of labeling and/ or readily accessible information regarding NT. Moreover, the information that does exist is

provided by industry and government and is almost unconditionally supportive of the technology. Most of the NT perception studies have similarly emphasized benefits of NT including industrial productivity, economic growth, and international trade (Thomas and Sayre, 2005). Likewise, media coverage has generally emphasized the benefits of nanotechnology, especially for industrial products. Very little coverage of NT has highlighted any potential risks of nanoparticles, especially in newspapers from the US (Kulve, 2006; Wilkinson *et al.,* 2007). These biases again contribute to a lack of balanced NT-associated information that is readily accessible to consumers.

Among the nine specific nanoproducts that were identified in this study, respondents from both countries ranked earlier detection of cancer as the highest priority and the group of products catering to human convenience (i.e. higher speed computing, effective sunscreens, and self cleaning fabrics) as the lowest priority. However, ranking varied between the two countries. Earlier detection of cancer (6.49 vs. 5.88, $p<0.005$) and more durable artificial hearts (5.00 vs. 4.49, $p<0.005$) were ranked higher in Canada as was the more effective cleanup of oil spills (5.24 vs. 4.93, $p<0.05$). More precise drug delivery systems were ranked higher in Korea (4.95 vs. 5.41, $p<0.005$) whereas respondents from that country ranked more effective sunscreens much lower (2.63 vs. 1.89, $p<0.0005$).

Trust and Concern of Nanotechnology

As with previous risk perception studies, public concerns regarding NT may arise from a lack of knowledge and a lack of effective communication that can help address any concerns (Cobb and Macoubrie, 2004; Small Talk, 2006). Korean respondents showed greater trust in scientists and in technology than did Canadians, but the Korean

public was more distrustful of the government. As will be discussed further below, this reflects the prominent role that science and technology play in the Korean economy (Lee, 2002), a country that, unlike Canada, has very few natural resources.

Korean respondents that were opposed to NT (factor 1) were more likely to be concerned about social ($p<0.0005$) and environmental ($p<0.05$) impacts and to desire greater public participation ($p<0.001$) in decision-making regarding NT. Proponents (factor 2), especially from Canada, were more likely to trust technology ($p<0.0005$) and were also less likely to be concerned about social ($p<0.001$) and environmental ($p<0.05$) impacts. Moreover, Canadian experts who were proponents had greater trust in science ($p<0.05$), scientists ($p<0.05$), and technology ($p<0.001$) and were less likely to support greater participation in decision-making regarding NT ($p<0.05$) than the public. Although much more likely to be knowledgeable of NT than the opponents, Canadian experts were much less likely to be concerned about any risks.

Interestingly, only Korean experts were likely to trust to the government ($p<0.1$). It may reflect the long-standing top-down vision approach to the identification of key technologies taken in Korea (Luther, 2004). While Korean conditional proponents (Factor 3) of NT were likely to trust scientists ($p<0.001$), they were also concerned about human health ($p<0.0005$). Korean experts that were conditional proponents had trust in scientists ($p<0.05$) but were less likely to be concerns about environment ($p<0.1$) and the Canadian public who were conditional proponents were more likely to distrust the technology ($p<0.05$) and were less likely to be concerned about any social impacts ($p<0.001$). This reflects the great priority that all respondents placed on human health regarding NT, regarding both potential benefits and risks. It also shows the conditional nature of the

support of this third group. It is unlikely that those opposed to NT or those that were unconditional proponents regarding NT would change their views. Indeed, recent research (Caplan *et al.,* 2000) suggests that any new information regarding NT simply reinforces those already existing viewpoints in groups that have extreme attitudes. However, all the questions emerging from the factor analysis regarding the conditional proponents contrasted the risks and the benefits surrounding NT. This suggests that any negative implications, especially ones surrounding human health, could have substantial implications for their views on NT.

Implications of differences in culture

Many similarities in attitudes towards NT existed between Canada and Korea. Both countries have the fastest growth rates of industries that make extensive use of NT, including semiconductor memory chips, shipbuilding and electronics (Lee, 2002). From 1976 to 2004, Canada ranked tenth (5,017) for NT-associated scientific publications whereas Korea ranked ninth (6,679) in the world (Li *et al.*, 2008). Canada is geographically located next and has close economic ties to the US, which has been the globe's greatest investor in NT. Likewise, Korea is located adjacent to China, Japan, and Taiwan, which have been also been fast accelerating their investment in the technology (Li *et al.*, 2008). All of these countries thus invest huge amounts of money and efforts in NT. It is thus reasonable to assume that both Canada and Korea would have and will continue to actively promote and adopt nanotechnology research and programs regardless of any potential risks. Indeed, little difference existed between Canada and Korea regarding NT and expertise of NT (p=0.991), trust in technology (p=0.875), attitudes

towards the environment (p=0.993), and concern for public input (p=0.747). Given these similarities, it is likely that comparable approaches to the development of this industry as well as the development of risk research and regulations should be undertaken.

Yet, there are also many differences between the two countries. The economy of Korea is arguably far more dependent on NT, and this dependence will likely only increase in the future. It has few natural resources, and places a great emphasis on industrial development as well as human resources and education. Manufacturing has played a tremendous role in the development of the Korean economy over the last 30 years, and Korean products are now exported around the world. In contrast, the manufacturing capacity in Canada has dropped over the same time period as it is a net importer of manufactured goods. Indeed, the economy of Canada (total exports of goods: $487,489 million CAD in 2008) is highly reliant on the export of natural resources (about 45% in 2008), such as agricultural and fishing products ($40, 856 million CAD), energy products ($125, 695 million CAD), forestry products ($25, 658 million CAD), and paperboard products ($10,091 million CAD) (Statistics Canada, 2008).

Of the independent variables that were examined attitudes toward nanotechnology from both Canada and Korea were strongly affected (p<0.0005 to p<0.05) by concern regarding social impacts, the environment, human health, and public input as well as trust in scientists, science, and technology. Other factors also had important (p<0.001 to p<0.05) influences on attitudes towards NT including expertise in NT, formal education, academic specialization, gender, age, religion, marriage status, and financial wellbeing (p<0.0005 to p<0.1). Canada is an ethnically diverse country and its population is British (28%), French (23%), other European (15%), or Aboriginal (2%) in origin or from Asia,

Africa, or the Middle East (6%), (HighBeam Research, 2009). In contrast, Korea is one of the world's most ethnically and linguistically homogeneous societies, except for about 20,000 Chinese (HighBeam Research, 2009).

Moreover, the public from Canada in this study was more religious. With respect to religion, the two countries differ dramatically. Almost half of Koreans have no religious affiliation (46%) whereas substantially fewer are Christians (26%), Buddhists (26%), Confucianist (1%), and other (1%) (HighBeam Research, 2009). In contrast, Canadians are much more likely to characterize themselves as religious and to be Christian (70%), Muslim (2%) and only a minority are likely to express no religious affiliation (16%) (HighBeam Research, 2009). There is generally a negative relationship between religiosity and the moral acceptability of NT in European countries (Scheufele *et al.*, 2008). Although religiosity affected levels of support in this study and has been shown to be of central importance in other studies (e.g. Brossard *et al.,* 2008; Scheufele *et al.,* 2008), knowledge of NT seems to be a better indicator than religious beliefs for understanding public and expert attitudes.

The nature of formal education also had a strong effect on attitudes towards NT in both countries. The public from Korea that were conditional proponents specializing in life science and humanities were less likely to emphasize the benefits of NT whereas experts from Canada specializing in engineering and life sciences were much more likely to emphasize the benefits. Although those trained in engineering and life sciences were more likely to be knowledgeable of NT and to have positive attitudes towards NT, outcomes from both countries showed that respondents trained in the life sciences were more likely to be conditional proponents. Other research suggests that income is

positively associated with attitudes towards NT (Sjoberg, 2000; Slimak and Dietz, 2006), and expert proponents from Korea in this study were more likely to be well off financially. However, the Korean public who were likely to be older and to be married were less likely to be conditional proponents.

Ultimately, these results show that understanding and managing the positive and negative attitudes are important for both public and experts. Although meaningful differences in attitude did exist between the two countries that were related to corresponding differences in culture, the divide in attitudes between public and experts remained a constant in both Canada and Korea. These results indicate a pressing need for wide ranging dialogue between public and experts and that the knowledge gaps and concern of nanotechnology should be adequately addressed if NT has any hope of being accepted by Canadian and Korean consumers in the future.

REFERENCES

Alhakamo, A. S., and Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis*,14, 1085-1096.

Amin, L, Jahi J. M, Nor, A. R. M., Osman, M., and Mahadi, N. M. (2007). Public acceptance of modern biotechnology. *Asia Pacific Journal of Molecular Biology and Biotechnology*,15, 39-51.

Boholm, Å. (1998). Comparative studies of risk perception: A review of twenty years of research. *Risk Research*, 1, 135-163.

Brookes, G. and Barfoot, P. (2006). GM crops: The first ten years- the global socio-economic and environmental impacts. *International Service for the Acquisition of Agri-biotech Application (ISAAA)*, 36, 1-116. Available at: http://www.isaaa.org/Resources/Publications/briefs/36/download/isaaa-brief-36-2006.pdf

Brossard, D., Scheufele, D. A., Kim, E., and Lewenstein, B. V. (2008). Religiosity as a perceptual filter: Examining processes of opinion formation about nanotechnology. *Public Understanding of Science. October.*

Burnham, K. P. and Anderson, D. R. (2002). Model selection and multimodel inference: A practical information-theoretic approach (2nd Edition). Springer, New York.

Byrnes, J. P., Miller, D. C., and Schafer, W. D. (1999). Gender differences in risk taking: A meta-analysis. *Psychological Bulletin*, 125, 367-383.

Caplan, P. (2000). Eating British beef with confidence: A consideration of consumers' responses to BSE in Britain. In P. Caplan (Ed.), Risk Revisited, 184–203.

Cobb, M. D. and Macoubrie, J. (2004). Public perceptions about nanotechnology: Risks, benefits and trust. *Journal of Nanoparticles Research*, 6, 95-405.

Cook, A. J. and Fairweather, J. R. (2005). Nanotechnology - ethical and social issues: results from New Zealand focus groups. Research Report No. 281. Canterbury, New Zealand: Lincoln University. Available at: http://www.lincoln.ac.nz/story_images/1330_rr281_s4140.pdf

Creswell, J. W. (2003). Research design: Qualitative, quantitative, and mixed methods approaches (2nd Edition). Sage, London.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297-334.

Cronin, K. E. (2004). From biotech to nanotech - Enhancing deliberative processes for

science and technology innovation. Victoria University of Wellington, Wellington, New Zealand. Available at: http://www.engagingcommunities2005.org/abstracts/Cronin-Karen-final.pdf

Davidson, D. J. and Freudenburg, W. R. (1996). Gender and environmental risk concerns: A review and analysis of available research. *Environment and Behavior,* 28, 302-339.

Douglas, M. (1985). Risk acceptability according to the social sciences. Russell Sage Foundation, New York.

ETC Group. (2007). Principles for the oversight of nanotechnologies and nanomaterials. Press Release: Broad International Coalition Issues Urgent Call for Strong Oversight of Nanotechnology. Available at: http://www.etcgroup.org/en/issues/nanotechnology.html

European Commission (2001). Eurobarometer survey on Europeans, Science and technology, European Commission. Available at: http://ec.europa.eu/research/press/2001/pr0612en-report.pdf

European Commission, Community Health and Consumer Protection. (2004). Nanotechnologies: A preliminary risk analysis on the basis of a workshop organized in Brussels on 1–2 March 2004 by the Health and Consumer Protection Directorate General of the European Commission. Available at: http://europa.eu.int/comm/health/ph_risk/events_risk_en.htm.

Fischhoff, B., Slovic, P., and Lichtenstein, S. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Journal of Policy Science*, 9, 127-152.

Finucane, M. L., Slovic, P., Mertz, C. K., Flynn, J., and Satterfield, T. A. (2000). Gender, race, and perceived risk: The White male effect. *Health, Risk, and Society*, 2, 159-172.

Frewer, L. (2003). Social issues and public attitudes towards genetically modified foods. *Trends Food Science Technology*, 14. 319-332.

Gabrial, I. J. and Nyshadham, E. (2008). A cognitive map of people's online risk perceptions and attitudes: An empirical study, Proceeding of the 41st Hawaii International Conference on System Sciences. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4438979 &isnumber=4438696

Gaskell, G. Allum, N., Wagner, W., Kronberger, N., Torgersen, H., Hampel, J., and Bards, J. (2004). GM foods and the misperception of risk perception. *Risk Analysis,* 24, 185-194.

Gaskell, G., Ten Eyck, T. T., Jackson, J., and Veltri, G. (2005). Imaging nanotechnology: Cultural support for technological innovation in Europe and the United States. *Public Understanding of Science*, 14. 81-90.

Greenpeace (2004). The European union's new labelling rules for genetically engineered food and feed. Available at: http://www.greenpeace.org/raw/content/usa/press-center/reports4/the-european-union-s-new-label.pdf

Grove-White, R., Kearens, M., Miller P., Macnaghten, P., Wilsdon, J., and Wynne, B. (2004). Bio-to-Nano?: Learning the lessons, interrogating the comparison. Institute for Environment, Philosophy and Public Policy, Lancaster University and Demos. Available at: http://www.nanoandsociety.com/ourlibrary/documents/bio+to+nano.pdf

Hatcher, L. (1994). A step-by-step approach to using the SAS system for factor analysis and structural equation modeling (3rd Edition). Cary, NC: SAS Institute Inc.

HighBeam Research. (2009). Ethnicity and Race by Countries. Available at: http://www.infoplease.com/ipa/A0855617.html

Kahan, D. M., Braman, D., Gastil, J., Slovic, P., and Mertz, C. K. (2007). Cultural and identity-protective cognition: Explaining the white-male effect in risk perception. *Journal of Empirical Legal Studies*, 4, 465-505.

Kearnes, M., Macnaghten, P., and Wilson, J. (2006). Governing at the nanoscale: People, policies and emerging technologies. Demos, London. Available at: http://www.demos.co.uk/files/governingatthenanoscale.pdf?1240939425

Korea National Statistical Office. (2005). Korean Statistical Information Service from Available at: http://www.kosis.kr

Kulve, H. T. (2006). Evolving repertoires: Nanotechnology in daily newspapers in the Netherlands. *Science as Culture,* 15, 367-382.

Lee, J. W. (2002). Overview of nanotecnology in Korea – A? 10 years blueprint. *Journal of Nanoparticle Research,* 4, 473-476.

Lemyre, L., Lee, J. E., Mercier, P., Bouchard, L., and Krewski, D. (2006). The structure of Canadians' health risk perceptions: Environmental, therapeutic and social health risks. *Health, Risk and Society*, 8, 185-195.

Li, X., Chen, H., Dang, C., Lin, Y., Larson, C. A., and Roco, M. (2008). A longitudinal analysis of nanotechnology literature: 1976-2004. *Journal of Nanoparticle Research,* 10, 3-32.

Luther, W. (2004). International strategy and foresight report on nanoscience and nanotechnology. Final Report, VDI Technologiezentrum GmbH, Future Technologies Division. March 19.

Macoubrie, J. (2006). Nanotechnology: public concerns, reasoning and trust in government. *Public Understanding of Science*, 15, 221-241.

Madison. (2005). Report of the Madison area citizen consensus conference on nanotechnology, Available at: http://www.nanocafes.org/files/consensus_conference_report.pdf

Mauro, I. J. and McLachlan, S. M. (2008). Farmer knowledge and risk analysis: Post release evaluation of herbicide-tolerant canola in western Canada. *Risk Analysis*, 28, 463-476.

Maxwell, J.A. (2005). Qualitative research design: an interactive approach. Sage Publications, Thousand Oaks, CA.

McCluskey, J. J., Grimsrud, K. M., and Wahl, T. I. (2004). Comparison of consumer responses to genetically modified foods in Asia, North America, and Europe. *Regulating Agricultural Biotechnology: Economics and Policy*, Chapter 11, 227-240.

Mehta, M. D. (2004). From Biotechnology and nanotechnology: What can we learn from earlier technology? *Technology and Society,* 24, 34-39.

Merzbacher, C. (2005). Nanotechnology: a policy perspective (office of science and technology policy), EPA Conference on Frontiers in Nanotechnology.

Monit, J. E. (2006). Small wonders, big future: The development of environmental nanotechnology. *Journal of Environmental Monitoring,* 8, 235-239.

Moon, W. and Balasubramanian, S. K. (2004). Public attitudes toward agrobiotechnology: The mediating role of risk perceptions on the impact of trust, awareness, and outrage. *Review of Agricultural Economics*, 26, 186-208.

Oltedal, S., Moen, B., Klempe, H., and Rundmo, T. (2004). Explaining risk perception. An evaluation of cultural theory. Rotunde, 85, 1-46. Available at: http://www.svt.ntnu.no/psy/Torbjorn.Rundmo/Cultural_theory.pdf

Powell, M. C. and Kanarek, M. S. (2006). Nanomaterial health effects-part 1: Background and current knowledge. *Wisconsin Medical Journal*, 105, 16-20.

Powell, M. C. and Kanarek, M. S. (2006). Nanomaterial health effects-part 2: Uncertainties and recommendations for the future. *Wisconsin Medical Journal*, 105, 18-23.

Priest, S. H. (2006). The North American opinion climate for nanotechnology and its products: Opportunities and challenges. *Journal of Nanoparticle Research*, 8, 563-568.

Priest, S. H. (1995). Information equity, public understanding of science and the biotechnology debate. *Journal of Communication*, 45, 39-54.

Rejeski, D. (2006). FDA and nanotechnology: Public perceptions matter. Project on Emerging Nanotechnologies, 1-11. Available at: http://www.nanotechproject.org/file_download/files/RejeskiFDA.pdf

Roco, M. C. (2005). The emergence and policy implications of converging new technologies integrated from the nanoscale. *Journal of Nanoparticles Research*, 7, 129-143.

Rogers-Hayden, T. and Pidgeon, N. (2006). Reflecting upon the UK's citizens' jury on nanotechnologies: NanoJury UK. *Nanotechnology Law & Business* (May/June), 167-178.

Roszek, B., de Jong W. H., and Geertsma, R.E. (2005). Nanotechnology in medical applications: State-of-the-art in materials and devices. *RIVM report.* Available at: http://lamp.tu-graz.ac.at/~hadley/nanoscience/references/RIVM.pdf

Royal Society. (2004). Nanoscience and nanotechnologies: Opportunities and uncertainties. Royal Society and Royal Academy of Engineering, London. Available at: http://www.nanotec.org.uk/finalReport.htm

Scheufele, D.A., Corley, E. A., Shih, T., Dalrymple, K. E., and Ho, S. S. (2008). Religious beliefs and public attitudes toward nanotechnology in Europe and the United Stated. *Nature Nanotechnology, 4, 91-94.*

Short, Jr., J. F., (1984). The social fabric at risk: toward the social transformation of risk analysis. *American Sociological Review,* 49, 711-725.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science and Technology,* 19, 603-608.

Siegrist, M., Keller, C., Kastenholz, H., Frey, S., and Wiek, A. (2007). Lay people's and experts' perception of nanotechnology hazards. *Journal of Risk Analysis*, 27, 59-69.

Sjoberg, L. (2000). Factors in risk perception. *Risk Analysis*, 20, 1-11.

Sjoberg, L. (2004). Principles of risk perception applied to gene technology. *European Molecular Biology Organization*, 5, 47-51.

Slimak, M. W. and Dietz, T. (2006). Personal values, beliefs, and ecological risk perception. *Journal of Risk Analysis,* 26, 1689-1705.

Small Talk. (2006). Small talk: Project report (London: Think-Lab)

Statistics Canada (2006, 2008).
Available at: http://www.statcan.gc.ca/start-debut-eng.html

TA-Swiss. (2006). Public reactions to nanotechnology in Switzerland. Report on publifocus discussion forum "nanotechnology, health, and the environment." TA-P 8/2006. Centre for Technology Assessment at the Swiss Science and Technology Council, Bern.

Tesh, S. N. (2000). Uncertain hazards. Cornell University Press.

The Technology Transfer Centre (TTC) (2007). Government funding, companies and applications in nanotechnology worldwide 2007.
Available at: http://www.euronanotrade.com/news/nanocommerc.doc

The World Bank. (2007).World development indicators database. Available at: http://siteresources.worldbank.org/DATASTATISTICS/Resources/GDP.pdf

Waldron, A. M., Spencer, D., and Batt, C. A (2006). The current state of public understanding of nanotechnology. *Journal of Nanoparticle Research*, 8, 569-575.

Waters, J. (2003). Global research and development (R & D) expenditure on nanotechnology.

Wilkinson, C., Allan, S., Anderson, A., and Petersen, A. (2007) From uncertainty to risk?: Scientific and news media portrayals of nanoparticles safety. *Journal of Health, Risk & Society*, 9,145-157.

Wilson, J. (2004). The Politics of small things: nanotechnology, risk, and uncertainty. *Technology and Society Magazine*, 4, 16-21.

Wood, S. (2005). Understanding the risks of the science of the small. A Report by the Jupiter Socially Responsible Investment (SRI) and Governance Team, October.

CHAPTER IV: Health and Environmental Risk Perceptions of Nanotechnology and Nanoproducts

4.1 ABSTRACT

Nanotechnology (NT) is generating increasing excitement with scientists, industry, governments, and indeed consumers around the world. Yet, there is a growing concern that there are also many attendant risks associated with NT-risks that have yet to be adequately characterized much less effectively managed. The overall goal of this study was to better understand public and expert attitudes regarding environmental and human health risks associated with nanotechnology. More specifically, I characterized attitudes towards NT, compared risks associated with NT to those associated with other health and environmental risks, and contrasted attitudes in Canada with those in South Korea.

Overall, almost half of the respondents from each country (49% in Canada vs. 47% in Korea) were at least somewhat worried about human health and environmental risks associated with NT. Canadians who were trusting of science and government were more interested in regulation, public input, and public consultation whereas Koreans who were trusting of scientists, technology, and industry were more likely to value increasing responsibility of nano-industries, social impacts, public debate, and public opinion in decision-making. Although respondents were much more concerned about NT-associated risks to human health than the environment, ways that these risks might be mitigated also varied, especially between the public and experts. Many respondents indicated they were concerned about NT-associated risks, yet these ultimately ranked much lower than other risks that threaten human health and the environment. Korean respondents were thus much more concerned about risks associated with nuclear power and respondents from

both countries were greatly concerned about avian influenza and global warming.

Interviews with experts provided greater detail on attitudes towards risks associated with nanotechnology and nano-materials. These potential risks were seen as best addressed, in decreasing order of importance, by increases in research, regulation, and more effective communication with the public. Of the 20 independent variables that played an important role in shaping attitudes regarding NT, increasing the accountability of nano-industries, regulation, and public debate were highly influential ($p<0.0005$) for respondents who recognized the need to address the substantial health and environmental risks. In contrast trust in scientists and companies and concern about potential social impacts were significantly associated ($p<0.0005$) with negative attitudes. With respect to demographic variables, expertise with NT was the most important ($p<0.0005$) in shaping attitudes, whereas gender, education, discipline, marriage status, financial wellbeing, and religion were less important ($p<0.001$ to $p<0.1$). However, it is also important to note that there seemed to be little overall awareness in either country as to how the public might become better informed and involved in decision-making, especially with respect to public opinion and consultation.

4.2 INTRODUCTION

Nanotechnology (NT) is a fast emerging technology that is generating much excitement with scientists, industry, governments, and indeed consumers around the world. It is multidisciplinary in approach, conventionally involving the fields of chemistry, physics, biology, material science and engineering, and, more recently toxicology, of nano-objects or nano-tools (Albrecht *et al.*, 2006; Grove-White *et al.*, 2004). The term "nano" refers broadly to materials, device, systems, and structures with nano-scale dimensions, usually ranging in size from 1 to 100 nanometres (nm) (Monit, 2006).

Nanomaterials ideally enhance the function and utility of a wide diversity of products. Already broadly available to consumers, they are now used in sunscreens, cosmetics, toothpastes, sanitary ware coatings, paper, plastics, paints, pharmaceuticals, sporting goods, electronics, and even food products amongst other products (Hoet et al., 2004; Roszek *et al.*, 2005; Wood, 2005). Many feel that nanoproducts also have great socio-economic, political, and even environmental benefits, including products that are lightweight, cheaper, stronger, and more durable than conventional ones (Bowman and Hodge, 2007). Applications containing nano-scale additives promise numerous environmental benefits including filter technology, energy technology, fuel technology, environmental monitoring, and environmentally sensitive manufacturing (Hannah and Thompson, 2008) and, by providing better packaging, also healthier food (Kuzma and VerHage, 2006; San-guansri and Augustin, 2006).

Some experts feel that existing regulations and assessments of potential hazards, exposure, and likelihood of toxic effects are adequate (Tsuji *et al.*, 2006). Indeed, many

experts insist that there is little-to-no evidence of any environmental and human health risks specific to NT (Burri, 2007; Handy and Shaw, 2007; Rejeski, 2006). Most research and media coverage has also focused on the benefits of NT. There has been little coverage of the potential risks of nanoparticles, especially in newspapers from the US, despite a recognized need for research and effective regulation (Kulve, 2006; Wilkinson *et al.,* 2007). Yet, there is a growing concern that there are also many attendant risks associated with NT that have yet to be adequately characterized much less effectively managed (Lösch, 2006; Rejeski, 2006).

At the nanoscale, physical, chemical, and biological properties of materials may differ in important ways from the properties of individual atoms and molecules or bulk matter (Thomas *et al.,* 2006). Nanoparticles may be released into the water or the air and ultimately contaminate the soil and groundwater where they may be mobile and travel significant distances by air or water (Hannah and Thompson, 2008; Wilson, 2004). The same properties that create much of the promise for nano-sized materials may make them relatively toxic to cells and organisms (Powell and Kanarek, 2006). Otherwise desirable properties including high surface reactivity and the ability to cross cell membrane may also have negative implications for human health and the environment (Hannah and Thompson, 2008; Hoet *et al.*, 2004; Kanarek, 2007). Engineered nanoparticles now incorporate a wide range of substances, including elemental metals and inorganic nanoparticles like titanium dioxide (TiO2) and zinc oxide (ZnO), and carbon-based fullerenes and their derivatives and composites which might be harmful to human, animal and affect how these materials move through ecological pathways (Albrecht *et al.*, 2006; Hannah and Thompson, 2008). These toxicological risks to human health and the

environment are only now being explored in any detail (ElAmin, 2006; Johnson, 2007), long after nanoproducts have become widely available on the marketplace.

However, nano-specific legislative regulation is still lacking not only in national but also international spheres, in part because nanomaterials are assumed to function in an equivalent way to bulk materials and are thereby subject to the same regulations (Miller and Senjen, 2008; Bowman and Hodge, 2007; Albrecht *et al.*, 2006; Katao, 2006). Indeed, there are no requirements for labeling and pre-marketing approval for products containing nano-scale materials anywhere in the world (Friends of the Earth, 2006; Boyce, 2007). The development and debate surrounding NT-specific regulations is becoming a priority and will likely increasingly focus on product safety, privacy and civil liberties, occupational health and safety, especially with respect to workers in the industry, intellectual property, as well as international and environmental law (Bowman and Hodge 2007; Helland, 2004; Katao, 2006). In the absence of adequate scientific evidence and regulation, some critics are calling for a moratorium on this technology (e.g., ETC Group, 2003; Friends of the Earth, 2006; Royal Society, 2004; Swiss Re, 2004).

In part to address these growing concerns, there has been increasing attention to better understand public concerns earlier and in some cases to engage the public in decision-making regarding NT, especially in the US (Council for Science and Technology, 2006), New Zealand (Cronin, 2004), UK (Jackson *et al.*, 2005), Australia (Commonwealth of Australia, 2005) and Germany (Nanologue, 2005). The Royal Society (2004) notably emphasized that public concerns and resistance to new technology can be effectively addressed by maintained public engagement and debates over NT-associated

risks and benefits. These inclusive processes generally act to mitigate consumer fears, including those associated with "regulatory failures" (Bowman, 2007; Cook and Fairweather, 2005; Kearnes *et al.*, 2006; Madison, 2005; Rogers-Hayden and Pidgeon, 2006; TA-Swiss, 2006).

This focus on the public dimensions of NT in part increases the diversity and comprehensiveness of risk evaluation, increases public understanding of associated science and technology, and increases the credibility and acceptability of any policy-making outcomes (Doubleday, 2007). Some of these attempts are wide in scale, such as in UK, whereas other initiatives are more intimate and include opportunities for discussion between the public and scientists (Bowman and Hodge, 2007). While, this dialogue allows NGOs and civil society groups to play a more important and visible role as watchdogs in the making of public policy and while it arguably focuses on the science of NT and the increase the scientific literacy of the public, it has yet to resonate with larger society (Michelson and Rejeski, 2006; Bowman and Hodge, 2007).

Public views of risk are generally broader and more complex than expert depictions, where uncertainty is aggravated by the dread, lack of trust in corporations, scientists, and regulators, and the potential consequences of any given technology (Cobb, 2004; Priest, 1995; Slovic, 1987). Two main approaches, the psychometric paradigm and socio-cultural theory, have been used to address the uncertainty of these issues, and have largely been promoted largely within disciplinary boundaries and in isolation from each other in order to better understand and characterize consumer attitudes towards the issue of trust and concern about new technologies (Marris *et al.*, 1998; McCluskey, Grimsrud, and Wahl, 2004; Lee *et al.*, 2005; Slimak and Dietz, 2006). Although studies located in the

psychological paradigm do incorporate social factors, they still emphasize individualist and realist accounts (Taylor-Gooby and Zinn, 2006). Psychometric studies contrasting expert and lay perceptions of hazards and benefits associated with NT (Besley *et al.*, 2008; Levy *et al.*, 2008; Savadori *et al.*, 2004; Siegrist *et al.*, 2007) reflect previous studies of biotechnology risk perceptions (Fife and Rowe, 1996; Sparks and Shepherd, 1994; Slovic, 1987). The cognitive recognition of trust and confidence play an important role in public perceptions and as confidence increases that public and expert attitudes become increasing similar and the technology is increasingly accepted (Priest, 1995; Robbins, 2001; Siegrist, 2000). Indeed, some argue that public concerns are not couched in terms of the technology itself but almost wholly in the social context which the hazard is identified and products are regulated (UKST, 2006).

The cultural approach (Leung and Bond, 1982) also provides important contributions to the understanding of risk perceptions and shows how underlying beliefs regarding trust and the environment shape attitudes; beliefs which are consistent within each world view (Marris *et al.*, 1998). Confidence in government further plays an important role in determining attitudes to biotechnology and NT, especially for experts (Siegrist *et al.*, 2007). Attitudes towards nuclear waste and power as well as trust in experts and authorities thus have a substantial impact on risk perception, while personal knowledge about nuclear waste disposal has no effect (Biel and Dahlstrand, 1995).

Yet, by extolling the virtues of NT, by insisting that nano-products are equivalent to bulk products, and by restricting the limited public dialogue to the underlying science, proponents of NT arguably have yet to learn from past mistakes regarding other emerging technologies, particularly biotechnology (Mehta, 2004; Priest, 2006). Thus, most of the

debate surrounding NT has focused on science-based approaches to risk evaluation, these centering on the combined likelihood and consequences of harm (Cohen, 1985). Although nanoproducts are being developed and are now released on the market in both Canada and South Korea (herein Korea), few studies have adequately explored the implications of this new technology in either country, much less compared how they contrast with one another. The overall goal of this study was to better understand public and expert attitudes regarding environmental and human health risks associated with nanotechnology. More specifically, I characterized attitudes towards NT, compared risks associated with NT to those associated with other environmental and health risks, and contrasted attitudes in Canada with those in Korea.

3. METHODS

3.1. Data collection

This study design was mixed methodology in approach (Creswell, 2003) and was approved by the Joint-Faculty Human Subject Research Ethics Board Protocol at the University of Manitoba (#J2007:113). A questionnaire was designed that assessed attitudes toward science and technology, the environmental, health and social implications of nanotechnology, and possible responses to any risks associated with NT. It consisted of seven-point Likert scaled and open-end questions. Twelve pages in length, it took 30-60 minutes to complete. The questionnaire was pre-tested with 10 students and five experts in Canada, helping ensure that its content and wording were appropriate. Themes included science and technology as well as the environmental, health and social implications of nanotechnology.

The survey was conducted from November, 2007 until May, 2008. In total, 975 questionnaires were completed: 513 in Canada and 462 in Korea. Sampling was stratified between students (n=488), the general public (n=398), and experts (n=95). Attempts were made to have an equal proportion of men and women represented as well as a broad range of ages, incomes, and education classes (Table 4.1). Interviews with the public were largely conducted in train stations and shopping malls in all the cities, and also at the airport in Winnipeg because of the small size of its train station. As a sign of appreciation, all participants were given a Korean bookmark ($3 USD value). Respondents were randomly recruited in the morning, afternoon, and evenings, in order to reflect a broad sample of the population in each city.

In total, both undergraduate (n=252) and graduate (n=236) students were recruited in

all four cities. For Korea, these included the School of Earth and Environmental Sciences and the Department of Materials Science and Engineering at Seoul National University in Seoul, the Department of Earth Systems and Environmental Sciences and the College of Engineering at Chonnam National University in Gwangju. For Canada, these included the Centre for Environment and the Division of Engineering Science at the University of Toronto in Toronto, and the Faculty of Environment, Earth, and Resources and the Faculty of Engineering at the University of Manitoba in Winnipeg.

Sampling was stratified according to engineering (n=301), environment (n=227), life sciences (n=95), and the general arts and humanities (n=229) programs of study. Interviews with experts were conducted in person, by email, or by telephone, these also occurring from November, 2007 until May, 2008. In total, 89 experts participated from Canada (n=48) and Korea (n=41) from academia (n=65), non-governmental organizations (n=12), industry (n=7), and government (n=5). These included researchers working in various fields of nanotechnology, such as biomedical, electrical, computer, and materials sciences as well as physics and chemistry. Moreover, it included researchers involved in nanotechnology in environmental fields including ecology, forestry, and geology. An additional group of experts (n=36) from Canada (n=4) and Korea (n=32) also responded to a series of open ended questions that focused the most important benefits and risks associated with nanoproducts; that identified ways in which to reduce and regulate any risks associated with nanomaterials or nanoproducts; and that explored ways in which to respond to any public concerns regarding perceived risks.

3.2. Data analysis

Overall, there was substantial interest on the part of randomly selected participants, and in general 50% of students and 41% of the general public, and 9% of experts that examined the survey agreed to partake in the research. Reasons for not participating in the research included, in declining order of importance: lack of time, lack of interest in NT, lack of knowledge regarding NT, and lack of interest in research as a whole. Specific disciplines of study that were recorded were assigned to five broader classes: none, general arts and humanities, environment, life sciences, and engineering (Table 4.1). Socio-demographic variables were summarized and assessed for homogeneity of variance using ANOVA test for equality of variance (SPSS version 16.0). Means and standard error were calculated for both dependent and independent variables. These were then compared between countries using two-tailed t-tests, and assessed as significant if $p <$ 0.0005.

Independent variables were constructed by categorizing trust in science, scientists, technology, government, companies and attitudes regarding nano-industries, regulation, social impacts, public input, public debate, public consultation, and public opinion. Additional independent demographic variables included gender, age, education, discipline, financial wellbeing, marriage status, expertise of NT, and religion (Table 4.1 and Table 4.4).

Factor analysis (varimax rotation) was used to identify attitudes towards NT (Table 4.2 and Table 4.3). Any loading on a factor that was at least 0.400 was assigned to a factor. Alpha coefficients were calculated to test the reliability of the Likert scale for each factor and associated questions (Cronbach, 1951). Any alpha values >0.60 were

considered satisfactory for internal consistency of a scale and appropriate for variable reduction (Hatcher, 1994). Differences in means for factor scores were compared between the two countries and between the public and experts using ANOVA. Seventeen independent variables were evaluated in both factor analysis, including two indices related to the context of possible solutions of human health risk (Table 4.2) and environmental risks (Table 4.3) associated with nanotechnology and nanoproducts. The two indices were based on an exploratory factor analysis. The principal factors method was used for the initial extraction process and varimax procedures were used to rotate the data (SPSS version 16.0). Surveys with three or more of missing values for these questions were eliminated, resulting in a sample size of 859. Differences in group means and standard error of the factor score between the two countries were analyzed using ANOVA and t-tests.

Linear multiple regression analyses were performed separately for Canadian and Korean samples regarding human health risks and environmental risks (SPSS version 16.0) (Table 4.5). The full regression model was conducted using a correlation by enter method with each three factors scores (Tables 4.2 and 4.3) and 20 independent variables (Tables 4.1and 4.4). Regression analyses were conducted separately for Canada and Korea and for the public and experts from each country. Expertise in NT was assessed according to responses to the question "I am knowledgeable about nanotechnology" which was measured with a seven-point Likert scale. Responses were classed into three groups: low (1-2), medium (3-5), and high (6-7) (Table 4.4), and the medium class was then eliminated from the analysis.

Qualitative data arising from open ended questions in the survey were recorded,

systematically evaluated and coded, and any emerging themes identified (Maxwell, 2005). These themes were then matched with quantitative findings. This mixed methods approach was used to both triangulate responses and to further elaborate upon and interpret the results.

Table 4.1. Descriptive statistics of the variables used in regression analysis.

Variable	Canada (N=513)		S. Korea (N=462)		
	Mean (*SE*)	Alpha	Mean (*SE*)	Alpha	Sig.[11]
Trust					
Trust Science[1]	11.31 (0.103)	0.62	11.05 (0.101)	0.67	0.071
Trust Scientist[1]	7.79 (0.090)	0.64	8.13 (0.091)	0.69	**0.009**
Trust Technology[1]	10.53 (0.099)	0.62	10.55 (0.101)	0.67	0.875
Trust Government[2]	3.52 (0.066)	0.64	3.29 (0.061)	0.69	**0.010**
Trust Company?[2]	2.96 (0.087)	0.63	3.27 (0.080)	0.69	**0.007**
Reflexivity					
Nano-Industries[1]	10.42 (0.084)	0.64	10.81 (0.086)	0.68	**0.001**
Regulation[1]	10.42 (0.082)	0.61	9.54 (0.089)	0.68	**<0.0005**
Social Impact[1]	7.25 (0.094)	0.64	8.09 (0.104)	0.69	**<0.0005**
Public Input[1]	10.38 (0.089)	0.61	10.34 (0.086)	0.65	0.747
Public Debate[1]	10.47 (0.138)	0.62	10.81 (0.108)	0.67	0.057
Public Consultation[3]	7.03 (0.105)	0.61	6.71 (0.098)	0.69	0.028
Public Opinion[1]	10.13 (0.110)	0.61	11.24 (0.100)	0.68	**<0.0005**
Demographics					
Gender[4]	0.54 (0.022)	0.64	0.55 (0.023)	0.69	n/a
Age [5]	1.46 (0.033)	0.64	1.41 (0.031)	0.69	0.329
Education [6]	4.08 (0.041)	0.64	3.95 (0.043)	0.69	0.031
Discipline[7]	3.08 (0.064)	0.64	3.39 (0.065)	0.70	**0.001**
Financial Wellbeing[8]	3.30 (0.045)	0.65	3.27 (0.036)	0.69	0.622
Marriage Status[9]	1.65 (0.042)	0.64	1.53 (0.042)	0.69	0.049
Expertise of NT [10]	1.82 (0.035)	0.64	1.82 (0.032)	0.69	0.994
Religion[2]	3.86 (0.096)	0.66	3.63 (0.099)	0.70	0.089

[1]Scale ranges from "strongly disagree" (2) to "strongly agree" (14).
[2]Scale ranges from "strongly disagree" (1) to "strongly agree" (7).
[3]Scale ranges from "strongly disagree" (2) to "strongly agree" (14).
[4] Scale ranges from "female" (0) to "male" (1).
[5]Scale ranges from "18-30" (1), "31-45" (2), "46-60" (3) and "61- over" (4).
[6]Scale ranges from "less than high school" (1), "high school graduate" (2), "some college" (3), "college graduate" (4), and "post-graduate" (5).
[7] Scale ranges from "none" (1), "sociology" (2), "environment" (3), "life science" (4), and "engineering" (5).
[8]Scale ranges from "not enough" (1), "tight" (2), "no extra money" (3), "have extra money" (4), enough"(5).
[9]Scale ranges from "single" (1) "common-law" (2), "married "(3) and "divorced" (4).
[10]Scale ranges from "low" (1), "middle" (2), and "high" (3).
[11]Significant difference between the two countries for ANOVA

4. RESULTS

4. 1. Risk perceptions of nanotechnology and nanoproducts

Over 84% of respondents in Canada and 94% of those in Korea had heard of nanotechnology. Most (74% in Canada vs. 60% in Korea) were at least somewhat positive about NT. Some of the identified benefits focused on the properties of nanomaterials.

> *"Nanomaterials have new excellent physical and chemical properties that conventional technology could not achieve." (#971, Korea)*

whereas others focused on benefits associated with the products themselves.

> *" NT could achieve new functions, manufacturing new matter, reducing the need for energy and resources, and developing technology that covers a wide range of industries."(#863, Korea)*

Some respondents at least somewhat agreed (20% in Canada vs. 33% in Korea) that "nanomaterials will reduce the cost of consumer goods", although most did not know (32% vs. 18.4%) or were neutral (25% vs. 22%).

> *"NT is of better use, value, cost, and function and could result in products which are superior to conventional ones." (#888, Korea)*

Some proponents thought that any risks associated with NT were overstated and that nanoproducts would behave no differently from bulk products.

"As with other products, materials etc, we should not regard nanotechnology as 'exceptional'." (#892, Canada)

"No differently from any other potential hazards." (# 901, Canada)

Yet few of the respondents were knowledgeable about the technology (42% in Canada vs. 34% in Korea) (Table 4.1). This lack of familiarity affected the ability of some to respond to the research.

"Although I have some knowledge about nanoproducts and the technology, I am sorry that I could not answer the questions well because of my lack of knowledge of NT."(#106, Korea)

"I now realize that I have a very limited understanding and knowledge concerning NT. This led me to pick "neutral" concerning issues that I am unfamiliar with." (#944, Canada)

Others recognized that their lack of familiarity with NT, especially any risks, reflected the absence of accessible and balanced information surrounding both benefits and concerns.

"It is difficult to discuss risks associated with NT because of the lack of this kind of research compared to that of the benefits." (#887, Korea)

It is thus unsurprising that most respondents, especially those in Korea (50% vs. 75%), at

least somewhat disagreed that they had explored "the safety of nanoproducts." Yet this lack of familiarity with NT did not automatically translate into acceptance. Few (22% vs. 19%) agreed that the impacts of nanoproducts on human health were equivalent to those of conventional products, although many others did not know (29% vs. 26%) or were neutral (19% vs. 20%) (Table 4.2). Many recognized there were also potential unintended human health and environmental risks from nanotechnology and nanoproducts. Some of these risks were attributed to the smaller size of nanomaterials.

> *The main risk is that they are so small and will end up where they are not intended to." (# 891, Canada)*

> *"Risks of nano size are not well understood so that we do not know how much potential harm it would present for the environment and human health. However, it would be harmful because it is much smaller size" (#884, Korea)*

This small size might, in turn, affect rates of absorption within organisms, mutation and operate in the broader environment.

> *"Possible DNA disruptions on the genome of plants, humans, and animals might be seen." (#929, Canada)*

> *"Although less researched it* [NT] *can easily create problems for the environment and human health, in part because they can freely penetrate blood stream and even enter nerve tissue."(#973, Korea)*

4.2. Relative importance of human health and environmental risks between Canada and South Korea

Despite these concerns, health and environmental risks associated with NT were generally ranked much lower than those associated with other widely recognized threats. Indeed, human health risks associated with NT were ranked the lowest of any risks for both countries (Figure 4.1). In contrast, in descending order importance, air pollution, smoking, and poverty were seen as the greatest threats to human health. In general, there was much agreement in the relative ranking of these risks between Canada and Korea, although Canadians ranked poverty and Koreans ranked GM food much higher. When absolute values were compared, Koreans were significantly more concerned about GM food ($p<0.0005$), nuclear power ($p<0.0005$) and global warming ($p<0.001$) whereas Canadians were more concerned about poverty ($p<0.0005$), smoking ($p<0.0005$) and air pollution ($p<0.001$) (Figure 4.1).

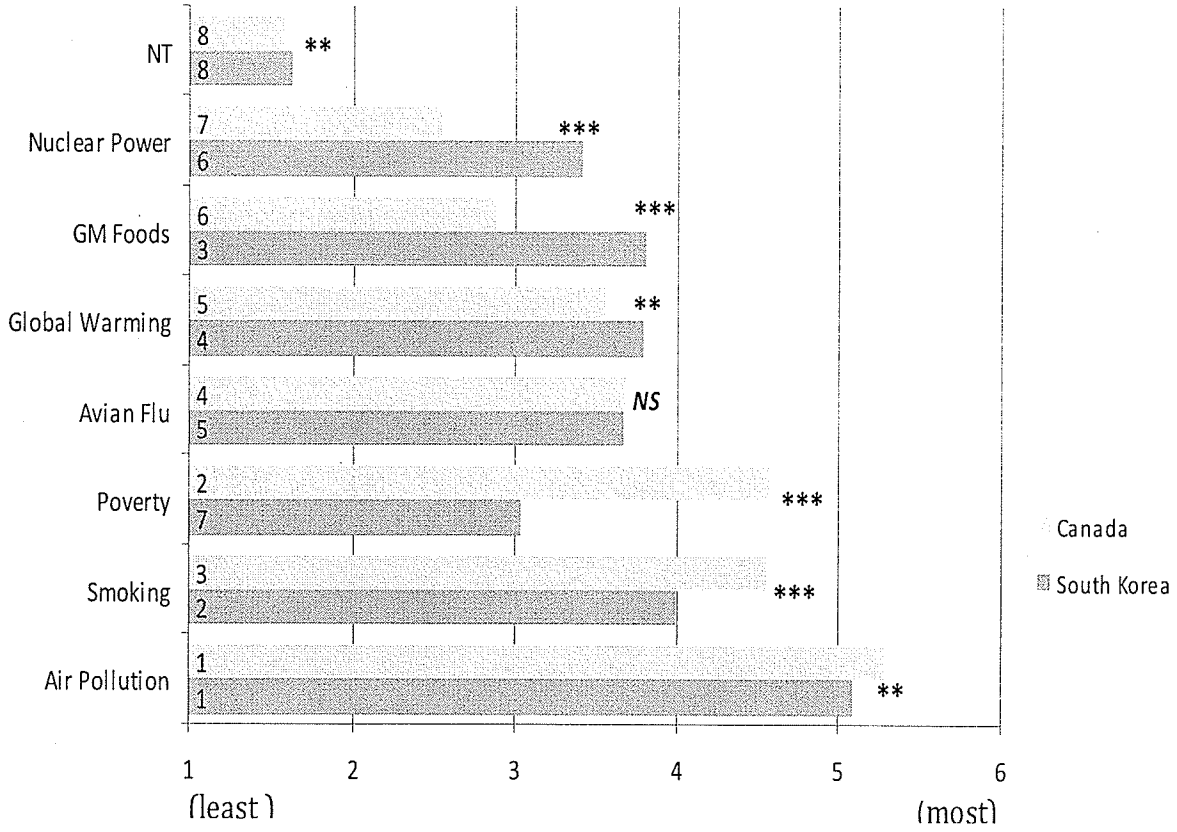

Figure 4.1. Differences in the ranking of human health risks between Canadian and South Korean respondents. Scale ranges from "least important" (1) to "most important" (8).*NS*: non-significant, *p= 0.65, ** p< 0.2, *** p< 0.0005

Likewise, environmental risks associated with NT were ranked much lower than other risks confronting the environment (Fig 4.2). Indeed, it and smoking were ranked as the lowest two risks by respondents from both countries. In contrast, risks associated with climate change and air pollution were seen as the most important. There again was much agreement in the relative ranking of these risks between Canada and Korea, although poverty was seen as a lower risk by Koreans (Figure 4.2). When absolute values were compared, Canadians were significantly more concerned about poverty (p<0.0005) and air pollution (p<0.0005) whereas Koreans were more concerned about GM foods

(p<0.001), nuclear power (p<0.0005), and global warming (p<0.001) (Figure 4.2).

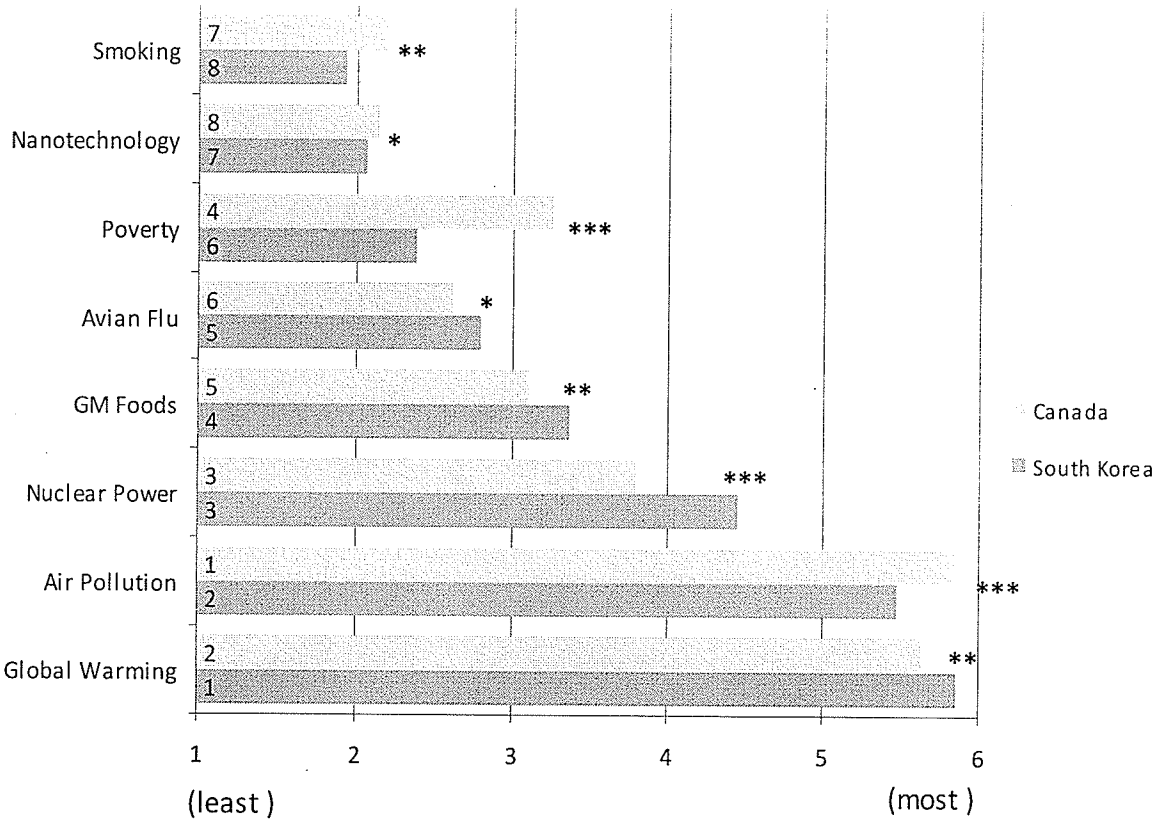

Figure 4.2. Differences in the ranking of environmental risks between Canadian and South Korean respondents. Scale ranges from "least important" (1) to "most important" (8). *NS*: non-significant, *p< 0.5, **p< 0.05, ***p< 0.0005.

Table 4.2. Outcomes of factor analysis and descriptive statics of human health risks from nanotechnology and nanoproducts in Canada and South Korea

Var.	Statements[1]	Factor Loading		Canada (n=513)		S. Korea (n=462)		
		Factor 1[2]	Factor 2[3]	Mean (*SD*)	Alpha	Mean (*SD*)	Alpha	Sig.[4]
H1	Industry should be required to provide information on the safety of their nanoproducts	**0.84**	0.06	6.22 (0.047)	0.75	6.24 (0.043)	0.65	0.777
H2	All nanoproducts must be clearly labeled as containing nanomaterials	**0.83**	0.05	5.86 (0.061)	0.74	6.17 (0.044)	0.64	**<0.0005**
H3	Adequate safety guidelines should be publicly available for all nanomaterials	**0.76**	0.11	6.18 (0.049)	0.75	5.92 (0.048)	0.64	**<0.0005**
H4	Due to their unknown risks, nanomaterials must receive additional scrutiny and testing	**0.76**	0.15	5.94 (0.061)	0.75	5.87 (0.056)	0.64	0.388
H5	Government should regulate risks associated with nano-products	**0.70**	0.14	5.79 (0.057)	0.75	5.65 (0.062)	0.63	0.107
H6	NT will significantly accelerate medical progress	0.12	**0.74**	5.95 (0.065)	0.73	5.90 (0.052)	0.66	0.608
H7	By lowering costs of medicines, NT will increase their availability to the poor	-0.03	**0.73**	5.36 (0.085)	0.74	4.92 (0.082)	0.67	**<0.0005**
H8	Benefits of nanomedicines outweigh any risks	0.22	**0.70**	5.00 (0.100)	0.75	4.18 (0.083)	0.74	**<0.0005**
H9	The impacts of nanoproducts on human health are no different from non-nanoproducts	0.10	**0.66**	5.34 (0.104)	0.76	4.87 (0.101)	0.71	**0.001**

Extraction method: principal component analysis.
Rotation method: Varimax with Kaiser Normalization.
[1]All scale ranges from "strongly disagree" (1) to "strongly agree" (7).
[2]Variables comprising the "possible solutions of the human health risks (H1-H5)" index.
[3]Variables comprising the "benefits of human health risk issues (E6-E8)" index.
[4]Significant difference between the two countries for ANOVA.

Table 4.3. Outcomes of factor analysis and descriptive statics of environmental risks from nanotechnology and nanoproducts in Canada and South Korea

Var.	Statements[1]	Factor Loading		Canada (n=513)		S. Korea (n=462)		Sig.[4]
		Factor 1[2]	Factor 2[3]	Mean (*SE*)	Alpha	Mean (*SE*)	Alpha	
E1	We need to assess environmental risks associated with nanomaterials.	**0.85**	0.11	6.20 (0.049)	0.80	5.89 (0.049)	0.76	**<0.0005**
E2	We need more independent research on the environmental impacts of nanoproducts.	**0.83**	0.09	6.15 (0.050)	0.80	5.90 (0.050)	0.77	**<0.0005**
E3	Environmental impacts should be assessed for every stage of a nanoproduct's lifespan.	**0.81**	0.11	6.08 (0.059)	0.80	5.91 (0.050)	0.76	0.023
E4	International environmental regulations are needed for NT.	**0.79**	0.13	5.91 (0.059)	0.80	5.89 (0.055)	0.77	0.823
E5	Release of nanomaterials should be delayed due to their potential effects on environment.	**0.62**	0.35	5.62 (0.072)	0.79	5.00 (0.081)	0.77	**<0.0005**
E6	Environmental risks associated with NT are exaggerated.	0.04	**0.85**	5.31 (0.096)	0.80	4.95 (0.092)	0.78	**0.007**
E7	Nanoproducts will ultimately benefit the environment.	0.08	**0.82**	5.46 (0.089)	0.80	5.13 (0.098)	0.77	0.014
E8	Environmental risks posed by nanoproducts are outweighed by the benefits they represent.	0.15	**0.73**	4.95 (0.098)	0.80	5.21 (0.079)	0.76	0.040

Extraction method: principal component analysis.
Rotation method: Varimax with Kaiser Normalization.
[1]All scale ranges from "strongly disagree" (1) to "strongly agree" (7).
[2]Variables comprising the "possible solutions of environmental risks (E1-E5)" index.
[3]Variables comprising the "benefits of environmental risk issues (E6-E8)" index.
[4]Significant difference between the two countries for ANOVA.

4.3. Factors underlying attitudes toward nanotechnology and nanoproducts risks in Canada and South Korea

1) Responses to human health risks

When potential human health risks associated with NT were examined in greater detail, two underlying factors emerged, the first and second factors accounting for 38%, and 19%, respectively, of the total 58% variance in response (Table 4.2). Cronbach's alpha values were acceptable and averaged 0.77 to 0.70 for Canada and Korea, respectively. Respondents concerned about health risks and desiring greater regulation separated out on factor 1 and emphasized concerns about nanomaterials.

> *"The material can cause harmful impacts to human body because it flows into The respiratory and gastrointestinal tract and is distributed throughout the vascular, liver, organ, and nerve systems, creating more active oxygen, causing inflammation, or influencing human health in the process of proliferation." (#877, Korea)*

Risks associated with at least some nanoproducts were also identified as important.

> *"Depends on the product: e.g., nanopowders would include respiratory concerns" (# 901, Canada).*

Canadian and Korean respondents both felt that "industry should be required to provide information on the safety of their nanoproducts" (6.22 vs. 6.24) and that "nanomaterials

must receive additional scrutiny and testing" because of the unknown risks (5.94 vs. 5.87). Likewise, respondents from both countries felt that governments should regulate risks associated with nano-products (5.79 vs. 5.65). However, Korean respondents were more likely to support the labeling on nanoproducts (5.86 vs. 6.17, $p<0.0005$) and Canadian respondents were more likely to advocate for an increased availability of safety guidelines to the public (6.18 vs. 5.92, <0.0005). In contrast, respondents emphasizing the importance of the health benefits associated with NT separated out on factor 2 (Table 4.2).

> *"Although NT might possibly harm the environment during manufacturing, I do not think it would be harmful, at least, to humans."(#307, Korea)*

> *"Major benefits would be new materials and hyper-reliable technologies, as well as medical feats and miracle repairs of organs and "better" organs etc." (#929, Canada)*

Proponents from both Canada and Korea felt that NT would accelerate medical progress (5.95 vs. 5.90) and those from Canada were more likely to view benefits of nanomedicines as greater than the risks (5.00 vs. 4.18, $p<0.0005$). Canadians were more likely to at least somewhat agree that the impacts of nanoproducts on human health were equivalent to non-nanoproducts (5.34 vs. 4.87, $p<0.001$). Moreover, Canadians were more likely to feel that NT would increase the availability of medicines to the poor (5.36 vs. 4.92, $p<0.0005$) (Table 4.2). Overall, Canadian respondents had stronger opinions

regarding health risks than Koreans.

2) Responses toward environmental risks

As with human health, questions relating to environmental risks sorted out on two factors, the first and second accounting for 42%, and 19%, respectively, of the total 61% in variance (Table 4.3). Cronbach's alpha values were again acceptable and averaged 0.82 and 0.79 for Canadian and Korean responses, respectively. Respondents concerned about the adverse implications of NT for the environment separated out in factor 1.

> *"In addition to the technology, I hope people will not forget about the importance of environment. The downfall of the environment is the destruction of all human beings." (#307, Korea)*

Interestingly, many, especially in Korea (27% in Canada vs. 42% in Korea), at least somewhat agreed that NT would "have substantial environmental risks" although an even greater proportion was neutral or did not know (54% vs. 41%). Few, especially in Canada, indicated that they would knowingly use nanoproducts that had demonstrated environmental risks (9% vs. 64%). Respondents from both countries felt that potential impacts should be assessed at every stage of a nanoproduct's life cycle (6.08 vs. 5.91) and that international environmental regulations were needed (5.91 vs. 5.81). Yet a delay in the release of nanomaterials due to potential environmental impacts received less support, especially in Korea (5.62 vs. 5.00, $p<0.0005$). Instead, respondents, especially those from Canada, felt that the environmental risks should be assessed (6.20 vs. 5.89, $p<0.0005$)

and that there was a need for more independent research on environmental impacts (6.15 vs. 5.90, $p<0.0005$). Respondents who were unconcerned about any environmental risks associated with NT separated out on factor 2. Those from both countries felt that nanoproducts would ultimately benefit the environment (5.46 vs. 5.13).

> *"Electronic automobiles, which get energy from the sun or hydrogen fuel-cell cars, and light, strong cars, which apply carbon nanotubes reducing their weight, should save oil and protect against global warming."(#856, Korea)*

Likewise respondents, especially those from Canada, felt that potential environmental risks associated with NT were exaggerated (5.31 vs. 4.95, $p=0.007$) (Table 4.3) or that nanoproducts and bulk products had equivalent risks.

> *"Ther e are no additional risks from nanoelectronics as compared with microelectronics" (# 901, Canada)*

As with health concerns, Canadian respondents were generally more likely to indicate strong opinions of both environmental risks (5.99 vs. 5.72) in E1 to E5 and the absence of risks (5.24 vs. 5.09) in E6 to E8 than their Korean counterparts. Some thought that these environmental risks should not be generalized and that potential risks might differ between material and product.

> *"Nanostructures materials likely possess very few environmental health issues,*

whereas the issues concerning nano-particles are unclear so far." (#735, Canada)

Others further felt that these risks would vary among products and should be evaluated on a case-by-case basis.

Table 4.4. Constructed independent variables and statements used in multiple regression

Variable	Description
Expertise of NT [1]	1. I am knowledgeable about nanotechnology. [2]
Trust government [2]	1. I trust government
Trust science [3]	1. I am excited about the value of science for humanity. 2. Science is about truth.
Trust scientist [3]	1. I trust scientists. 2. Scientists have proven the safety of nanoproducts.
Trust technology [3]	1. I think technology is central to solving problems facing humanity in the future. 2. I am interested in nanotechnology
Trust company [3]	1. Nanocorporations deserve tax incentives to promote NT.
Nano-industry[3]	1. Nano-industries should be legally responsible for negative impacts of their products. 2. Industry will benefit more from NT than consumers.
Regulation[3]	1. Global control standards should be developed for NT. 2. Risks with NT can be meaningfully reduced by regulation.
Social impact [3]	1. It is fine that profit rather than human need drives NT research. 2. If we enhance human capacities with NT, this will hurt those that now have disabilities.
Public input [3]	1. The public should be meaningfully involved in decisions about new technology. 2. The public should participate in decision-making regarding NT.
Public debate [3]	1. Hearing a debate between critics and supporters of NT would be useful in informing my opinion on NT. 2. Health risks of NT should be debated publicly.
Public consultation[3]	1. Public consultation should begin early, before nanoproduct design. 2. Would you like to see more public consultation regarding NT?[4]
Public opinion[3]	1. Managing risks associated with new technology should be largely directed by both the public and experts. 2. The opinions of the public on risks associated with new technology are as valid as those of scientists.

[1]Scale ranges from "low (1), middle (2), and high (3)."
[2]Scale ranges from "strongly disagree" (1) to "strongly agree" (7).
[3]Scale ranges from "strongly disagree" (2) to "strongly agree" (14).
[4]Scale ranges from "no (1), do not know (2), yes (3).

4. 4. Comparison of attitudes between Canada and South Korea

The role of independent variables on attitudes towards human health and environmental risks associated with NT were evaluated and compared between Canada and Korea (Table 4.5). These variables related to trust in science and technology, the role of the public, and socio-demographics. The role of independent variables on attitudes towards human health and environmental risk associated with NT were evaluated and compared between Canada and Korea (Table 4.5). These variables related to trust in science and technology, role of the public, and demographics.

In general, of the independent variables that played an important role in shaping attitudes regarding NT, those including trust in scientists, companies, nano-industries, and regulation were all highly significant ($p<0.0005$) for respondents who recognized the need to address the substantial health and environmental risks (factor 1). Moreover, trust in companies and social impacts played an important role ($p<0.0005$) for respondents who identified primarily with NT-associated benefits regarding human health and environment risk (factor 2). Only public debate was important ($p<0.0005$) in both factors. Expertise in NT ($p<0.0005$) was significant for those concerned about human health (factor 2) whereas gender, education, discipline and religion all had explanatory power ($p<0.05$) when comparing responses from Canada and Korea for both environmental and health risks (Table 4.5).

1) Human health risks

Respondents from Canada and Korea concerned about health risks and desiring greater regulation associated with NT had separated out on factor 1 (Table 4.2). They

desired greater regulation, in turn distrusting scientists (β = - 0.17, - 0.09), corporations, (β = - 0.18, - 0.16), and the nano-industry (β = - 0.18, -0.27). They further desired greater input during the development of regulation (β = 0.41, 0.21). Those from Korea were likely more to value public debate (β = 0.23) regarding NT and were more likely to be male (β = - 0.09). In contrast, those from Canada valued public input regarding these risks (β = 0.14), were more likely to be religious (β = 0.08) and more likely to be educated in the humanities and the arts than in engineering and the life sciences (β = - 0.13) (Table 4.5).

Respondents highlighting health benefits (Factor 2) associated with NT from both Canada and Korea were more likely to trust scientists (β = 0.10, β = 0.17), and were more likely to dismiss the importance of social impacts (β = -0.21, β= - 0.08) and of public debate (β = - 0.12, β= - 0.20) (Table 4.5). Respondents from Canada were more likely to be female (β = 0.09), less likely to be knowledgeable of NT (β = - 0.18), and more likely to be religious (β = 0.10). In contrast, those from Korea were more likely to trust science (β = 0.16) and were likely to value regulation (β = 0.11) and to be trained in engineering and the life sciences (B= - 0.15) (Table 4.5).

2) Environmental risks

Respondents from both Canada and Korea (factor 1) that were concerned about NT and desired more information and regulation (β = 0.35, β = 0.21) regarding associated environmental risks again distrusted scientists (β = - 0.16, β = - 0.09) and corporations (β = - 0.15, β = - 0.16). They were interested in increasing responsibility of the nano-industry as a whole (β = 0.20, β = 0.27) and tended to be male (β = - 0.12, β = - 0.09) (Table 4.5). Those from Korea desired greater public debate (β = 0.23) whereas those

from Canada had higher formal education (β = 0.09), were more religious (β = 0.08), financially better of (β = - 0.07), and more knowledgeable of NT (β = - 0.09).

In contrast, respondents from both Canada and Korea (factor 2) who felt there were few, if any environmental risks associated with NT, distrusted the NT companies (β= - 0.12, β = - 0.14) and were less interested in social impacts (β= - 0.21, β = - 0.09). Canadian respondents were less likely to value public opinion (β= - 0.12) and were more knowledgeable of NT (β= - 0.11) and more religious (β= 0.10) while those from Korea trusted science (β = 0.16) and scientists (β = 0.17), were interested in regulation (β = 0.11), and tended to be trained in engineering and the life sciences (Table 4.5).

Table 4.5. Role of independent variables in shaping attitudes towards human health and environmental risks associated with nanotechnology and nanoproducts for Canada and South Korea

	HUMAN HEALTH RISKS		ENVIRONMENTAL RISKS	
	Canada (n=431)	Korea (n=439)	Canada (n=430)	Korea (n=439)
Variable +Factor	Beta t value	Beta t value	Beta t value	Beta t value
Factor 1: Risks				
Trust Science	*NS*[1]	*NS*	*NS*	*NS*
Trust Scientist	-0.17 -3.86 (***)	-0.09 -1.88 (*)	-0.16 -3.36 (**)	-0.09 -1.88 (†)
Trust Technology	*NS*	*NS*	*NS*	*NS*
Trust Government	*NS*	*NS*	*NS*	*NS*
Trust Company	-0.18 -4.20 (***)	-0.16 -3.70 (***)	-0.15 -3.28 (**)	-0.16 -3.70 (***)
Nano-industries	0.18 3.98 (***)	0.27 5.63 (***)	0.20 4.17 (***)	0.27 5.63 (***)
Regulation	0.41 9.48 (*)	0.21 4.79 (***)	0.35 7.58 (***)	0.21 4.79 (***)
Social Impact	*NS*	*NS*	*NS*	*NS*
Public Input	0.14 2.58 (*)	*NS*	*NS*	*NS*
Public Debate	*NS*	0.23 4.90 (***)	*NS*	0.23 4.90(***)
Public Consultation	*NS*	*NS*	*NS*	*NS*
Public Opinion	*NS*	*NS*	*NS*	*NS*
Gender	*NS*	-0.09 -2.20 (*)	-0.12 -2.75 (*)	-0.09 -2.20 (*)
Age	*NS*	*NS*	*NS*	*NS*
Education	*NS*	*NS*	0.09 2.05 (*)	*NS*
Discipline	-0.13 -2.85 (*)	*NS*	*NS*	*NS*
Financial Wellbeing	*NS*	*NS*	-0.07 -1.67 (†)	*NS*
Marriage Status	*NS*	*NS*	*NS*	*NS*
Expertise of NT	*NS*	*NS*	-0.09 -1.75 (†)	*NS*
Religion	0.08 2.04 (*)	*NS*	0.08 1.82 (†)	*NS*
Factor 2: Benefits				
Trust Science	*NS*	0.16 2.21 (*)	*NS*	0.16 2.21 (*)
Trust Scientist	0.10 1.73 (†)	0.17 3.16 (*)	*NS*	0.17 3.16 (*)
Trust Technology	*NS*	*NS*	*NS*	*NS*
Trust Government	*NS*	*NS*	*NS*	*NS*
Trust Company	*NS*	*NS*	-0.12 -2.34 (*)	-0.14 -2.71 (***)
Nano-industries	*NS*	*NS*	*NS*	*NS*
Regulation	*NS*	0.11 2.14 (*)	*NS*	0.11 2.24 (*)
Social Impact	-0.21 -3.91 (***)	-0.08 -1.70 (†)	-0.21 -3.97 (***)	-0.09 -1.70 (†)
Public Input	*NS*	*NS*	*NS*	*NS*
Public Debate	-0.12 -2.13 (*)	-0.20 -3.85 (***)	*NS*	-0.20 -3.85 (***)
Public Consultation	*NS*	*NS*	*NS*	*NS*
Public Opinion	*NS*	*NS*	-0.12 -1.92 (*)	*NS*
Gender	0.09 1.76 (†)	*NS*	*NS*	*NS*
Age	*NS*	*NS*	*NS*	*NS*
Education	*NS*	*NS*	*NS*	*NS*
Discipline	*NS*	-0.15 -2.85 (*)	*NS*	-0.15 -2.85(*)
Financial Wellbeing	*NS*	*NS*	*NS*	*NS*
Marriage Status	*NS*	*NS*	*NS*	*NS*
Expertise of NT	-0.18 -3.24 (***)	*NS*	-0.11 -1.91(*)	*NS*
Religion?	0.10 2.19 (*)	*NS*	0.10 2.04 (*)	*NS*

Coding used for dependent variables indicated in Table 4.1 and 4.4.

[1]*NS*: non-significant and significant at †$p< 0.10$ *$p< 0.05$; **$p< 0.001$; ***$p< 0.0005$.

Table 4.6. Comparison of public and expert attitudes towards health and environmental risks identified by factor analysis for Canada and South Korea

Var.[1]	Canada				Sig.[2].	Korea				Sig.[3]	Sig.[4]	Sig.[5]
	Public (n=149)		Expert (n=123)			Public (n=80)		Expert (n=74)				
	Mean (*SE*)	Alpha	Mean (*SE*)	Alpha		Mean (*SE*)	Alpha	Mean (*SE*)	Alpha			
H1	6.36 (0.09)	0.88	6.07 (0.10)	0.84	**0.035**	6.39 (0.10)	0.89	6.15 (0.11)	0.74	0.120	0.824	0.629
H2	6.17 (0.10)	0.88	5.48 (0.16)	0.83	**<0.0005**	6.25 (0.11)	0.89	6.15 (0.11)	0.73	0.520	0.598	**0.002**
H3	6.45 (0.08)	0.89	5.96 (0.10)	0.84	**<0.0005**	5.91 (0.13)	0.89	5.97 (0.12)	0.73	0.725	**<0.0005**	0.931
H4	6.23 (0.11)	0.89	5.42 (0.14)	0.83	**<0.0005**	6.11 (0.14)	0.88	5.55 (0.19)	0.72	0.017	0.525	0.572
H5	6.03 (0.10)	0.89	5.51 (0.12)	0.84	**0.001**	5.90 (0.15)	0.88	5.43 (0.17)	0.72	0.043	0.474	0.691
H6	6.30 (0.13)	0.88	5.92 (0.10)	0.84	0.025	5.89 (0.15)	0.89	6.24 (0.11)	0.75	0.059	0.047	0.040
H7	5.74 (0.17)	0.89	5.03 (0.15)	0.84	**0.002**	5.30 (0.23)	0.89	5.11 (0.18)	0.75	0.514	0.119	0.75
H8	5.41 (0.21)	0.88	4.68 (0.18)	0.84	0.010	4.05 (0.24)	0.89	4.62 (0.20)	0.78	0.069	**<0.0005**	0.824
H9	6.17(0.20)	0.88	4.77 (0.19)	0.86	**<0.0005**	5.98 (0.24)	0.89	3.81 (0.21)	0.75	**<0.0005**	0.542	**0.001**
E1	6.32 (0.10)	0.89	6.00 (0.09)	0.84	0.018	6.02 (0.13)	0.88	5.97 (0.11)	0.74	0.763	0.070	0.853
E2	6.28 (0.09)	0.89	6.07 (0.09)	0.83	0.128	6.17 (0.13)	0.89	5.99 (0.11)	0.74	0.260	0.519	0.553
E3	6.38 (0.08)	0.89	5.66 (0.12)	0.84	**<0.0005**	6.00 (0.13)	0.89	5.76 (0.13)	0.73	0.190	0.012	0.612
E4	6.26 (0.10)	0.88	5.48 (0.14)	0.83	**<0.0005**	5.96 (0.15)	0.88	5.80 (0.13)	0.75	0.401	0.092	0.119
E5	6.11 (0.11)	0.88	5.08 (0.16)	0.83	**<0.0005**	5.68 (0.21)	0.89	4.62 (0.20)	0.75	**<0.0005**	0.045	0.074
E6	5.87 (0.19)	0.88	4.85 (0.16)	0.85	**<0.0005**	5.69 (0.25)	0.89	4.62 (0.20)	0.76	**0.001**	0.566	0.359
E7	5.73 (0.19)	0.88	5.25 (0.15)	0.84	0.050	5.52 (0.27)	0.88	4.89 (0.23)	0.76	0.081	0.520	0.169
E8	5.41 (0.21)	0.88	4.67 (0.166)	0.84	0.006	5.66 (0.22)	0.88	4.92 (0.18)	0.74	0.010	0.433	0.338

Coding used for independent variables indicated in Table 4.2 and 4.3.

[1]H1- H9 (Human Health Risks), E1- E8 (Environmental Risks)

[1] Significant difference between Canadian public and expert for ANOVA.

[2] Significant difference between Korean public and expert for ANOVA.

[3] Significant difference between Canadian public and Korean public for ANOVA.

[4]Significant difference between Canadian expert and Korean expert for ANOVA.

Table 4.7. Percentage of public and expert respondents responding to human health and environmental risks arising from nanotechnology and nanoproducts in Canada and South Korea

Var.[1]	Canada				S. Korea			
	% Public (n=149)		% Expert (n=123)		% Public (n=80)		% Expert (n=74)	
	+ /-	Neutral/ DK[2]	+ /-	Neutral/ DK[2]	+ /-	Neutral/ DK[2]	+ /-	Neutral/ DK[2]
H1	86.6/ 0.7	8.7/ 4.7	89.4/ 2.4	6.5/ 1.6	88.7/ 1.2	3.8/ 6.2	87.8/ 0	9.5/ 12.7
H2	**82.5**/ 1.3	10.7/ 5.3	**68.2**/ 13.0	14.6/ 14.1	86.2/ 1.2	6.2/ 6.2	90.6/ 1.4	5.4/ 2.7
H3	88.5/ 1.4	2.7/ 7.4	88.6/ 4.9	5.7/ 0.8	82.6/ 2.5	8.8/ 6.2	89.1/ 2.7	6.8/ 1.4
H4	78.5/ 2.7	7.4/ 11.4	71.5/ 10.6	14.6/ 3.3	80.1/ 5.0	5.0/ 10	78.4/ 9.5	9.5/2.7
H5	75.6/ 2.7	11.6/ 10.2	74.8/ 4.9	17.9/ 2.4	75.0/ 6.2	7.5/ 11.2	72.9/ 9.5	12.2/ 5.4
H6	**42.1**/ 0.7	16.6/ 40.7	**86.1**/ 2.4	4.9/ 6.5	60.8/ 3.8	12.5/ 15.0	**93.3**/ 2.7	2.7/ 1.4
H7	36.2/ 12.5	16.7/ 34.7	45.7/ 13.0	25.2/ 8.1	45/ 18.8	15.0/ 21.2	64.9/ 17.6	14.9/ 2.7
H8	**6.3**/ 28.5	20.8/ 44.4	**32.5**/ 27.6	25.2/ 9.8	20/ 45	21.2/ 13.8	**40.1**/ 27.0	21.6/ 1.4
H9	**11.0**/ 15.5	15.5/ 57.0	**36.6**/ 26.8	23.6/ 13.0	18.8/ 17.5	16.2/47.5	**17.6**/ 55.4	18.9/ 8.1
E1	86.5/1.4	6.8/5.4	88.8/0.8	9.8/0.8	78.8/ 3.8	8.8/ 8.8	93.2/ 1.4	5.4/ 29.7
E2	81.8/ 0.7	8.8/ 8.8	87.8/ 1.6	7.3/3.3	85/ 3.8	2.5/ 8.8	95.9/ 2.7	1.4/ 0
E3	**86.5**/ 0.7	7.4/ 5.4	**81.1**/ 5.7	11.5/ 1.6	76.2/ 2.5	10/ 11.2	87.8/ 5.4	5.4/ 1.4
E4	73.7/ 0.7	10.8/ 14.9	73.2/ 9.8	13.0/ 4.1	76.2/ 3.8	10/ 10	89.2/ 4.1	5.4/ 1.4
E5	**65.3**/ 1.4	15.0/ 18.4	**52.0**/ 20.3	18.7/ 8.9	**42.4**/ 11.2	18.8/ 27.5	**54.1**/ 28.7	14.9/ 1.4
E6	**8.2**/ 15.8	26.7/ 49.3	**44.0**/ 16.3	26.8/ 13.0	15/ 16.2	25/ 43.8	37.8/ 27	25.7/ 19.5
E7	9.8/ 14.7	29.4/ 46.2	48.8/ 8.1	30.1/ 13.0	7.6/ 22.5	25/ 45	28.4/ 21.6	31.1/ 18.9
E8	9.0/ 23.4	25.5/ 42.1	32.5/ 22.0	31.7/ 13.8	50/ 13.8	13.8/ 22.5	59.4/ 18.9	18.9/ 12.7

Coding used for independent variables indicated in Table 4.2 and 4.3

[1]H1- H9 (Human Health Risks), E1- E8 (Environmental Risks)

[2]DK: Do not know

4. 5. Public and expert attitudes in Canada and South Korea

Differences in attitude between public and expert attitudes towards health and environmental risks for Canada and Korea were substantial (Table 4.6). Generally, the public was significantly (p<0.0005) more likely to be concerned about health risks and to identify a need for regulation. The public in Canada was significantly (p<0.0005) much more likely to be concerned about risks and possible regulatory responses to risks (H1-H5) than experts. Yet, many respondents from the public were more neutral or indicated that they did not know: H6-H9 (mean: 62% vs. 66%) and E6-E8 (mean: 74% vs. 58%) on Factor 2 compared to experts: H6-H9 (mean: 30% vs. 18%) and E6-E8 (mean: 43% vs. 42%) (Table 4.7). The public in Canada was more likely to see value in labeling nanoproducts compared to experts (6.17 vs. 5.48, p<0.0005; 83% + vs. 68% +). The public in Canada was also more likely to indicate that NT would significantly accelerate medical progress (6.30 vs. 5.92, p<0.025; 42% + vs. 86% +), that the benefits of nanomedicines would outweigh any risks (5.41 vs. 4568, p<0.01; 6% + vs. 33% +), and that there was no difference in impacts on human health between nanoproducts and bulk products (6.17 vs. 4.77, p<0.0005; 11% + vs. 37% +) (Table 4.6 and Table 4.7).

When environmental risks were similarly examined, the public in Canada was somewhat more likely to see that environmental impacts should be evaluated at every stage of a nanoproduct's lifespan (6.38 vs. 5.66, p<0.0005; 87% + vs. 81% +) and that the release of nanomaterials should be delayed in Canada (6.11 vs. 5.08, p<0.0005; 65% + vs. 52% +) and in Korea, (5.68 vs. 4.62, p<0.0005) (42% + vs. 54% +). In contrast, experts were much more likely to assume that environmental risks were exaggerated (5.87 vs. 4.85, p<0.0005) (8% + vs. 44% +) (Table 4.6 and Table 4.7).

1) Role of independent variables in shaping public and expert attitudes

Regression analyses were used to contrast public and expert attitudes towards human health and environmental risks on NT and to evaluate the relationships of the independent variables in shaping these attitudes (Table 4.8 and 4.9). When public and expert perceptions were compared between Canada and Korea, the most important independent variables associated with human health and environment risks were nano-industries ($p<0.1$)) and regulation ($p<0.05$). Moreover, trust in scientists, companies, technology as well as public debate, age, marriage status, financial wellbeing, gender, and discipline were all significant ($p<0.1$) regarding potential risks and the need to address these (factor 1).

The most important demographic variables were age ($p<0.05$), marriage status ($p<0.1$), finance ($p<0.1$), discipline ($p<0.1$), and gender ($p<0.1$) regarding potential risks (factor 1). Academic specialization ($p<0.001$), education ($p<0.05$), marriage status ($p<0.1$), and gender ($p<0.1$) were also important in shaping the responses of those who primarily recognized NT-associated benefits (factor 2).

A. Human health risks

Public and expert respondents from Canada who were concerned about health risks (factor 1) desired more effective regulation ($\beta = 0.25$, $\beta = 0.43$) and distrusted scientists ($\beta = -0.28$, $\beta = -0.15$) (Table 4.7). The public from Canada distrusted companies ($\beta = -0.18$), wanted to increase the accountability of the nano-industry ($\beta = 0.38$), were against public opinion ($\beta = -0.18$) and debate ($\beta = -0.15$), and were more likely to be married ($\beta = 0.23$). Experts from Canada were likely to desire debate ($\beta = 0.32$), likely to be older ($\beta = 0.20$), and less likely to be trained in the engineering and life sciences ($\beta = -0.15$). When respondents from Korea were examined, the public was likely to trust scientists ($\beta = 0.38$), to be concerned about social impacts ($\beta = 0.21$)

whereas experts were unlikely to trust scientists (β = - 0.32) but were more likely to trust governments (β = 0.23) and nano-industry (β = 0.22). Additionally, they were more likely to value public debate (β = 0.40).). Although there was little ability to compare their responses, experts from both countries who were concerned about the risks were unlikely to trust scientists and were likely to value public debate (Table 4.8).

The implications of independent variables on the attitudes of proponents who viewed the benefits of NT (factor 2) were also examined. Experts from Canada were against regulation (β = - 0.20), were male (β = - 0.17), and valued public debate (β = 0.27). Lay proponents from Canada trusted scientists (β = 0.18), distrusted technology (β = - 0.20), distrusted companies (β = - 0.27), and valued public input (β = 0.24). When responses from Korea were examined, both experts and the public were critical of public debate (β = - 0.24, β = - 0.40). Experts trusted companies (β = 0.25) whereas the public was more likely to be educated primarily in the social sciences and humanities (β = - 0.36). When responses were compared across both countries, experts from Canada valued public debate whereas those from Korea did not (Table 4.8).

Table 4.8. Summary of multiple regression analysis examining the role of independent variables in shaping attitudes towards NT and human health for the public and experts in Canada and South Korea

Variable + Factor	HUMAN HEALTH RISKS			
	Canada		S. Korea	
	Public (n=126)	Expert (n=105)	Public (n=77)	Expert (n=66)
	Beta t value	Beta t value	Beta t value	Beta t value
F 1: Possible Solutions				
Trust Science	*NS*[1]	*NS*	0.38 1.90 (†)	*NS*
Trust Scientist	-0.28 -2.93 (*)	-0.15 -2.04 (*)	*NS*	-0.32 -2.28 (*)
Trust Government	*NS*	*NS*	*NS*	0.23 1.87 (†)
Trust Company	-0.18 -2.07 (*)	*NS*	*NS*	*NS*
Nano-industries	0.38 4.32 (***)	*NS*	*NS*	0.22 1.75 (†)
Regulation	0.25 2.91 (*)	0.43 4.94 (***)	*NS*	*NS*
Social Impact	*NS*	*NS*	0.21 1.56 (†)	*NS*
Public Debate	-0.15 -1.64 (†)	0.32 2.92 (*)	*NS*	0.40 3.12 (*)
Public Opinion	-0.18 -1.65 (†)	*NS*	*NS*	*NS*
Age	*NS*	0.20 2.32 (*)	*NS*	*NS*
Discipline	*NS*	-0.15 -1.77 (†)	*NS*	*NS*
Financial Wellbeing	*NS*	*NS*	*NS*	-0.19 -1.65 (†)
Marriage Status	0.23 2.47 (*)	*NS*	*NS*	*NS*
F2: Health Issues				
Trust Scientist	0.18 1.63 (†)	*NS*	*NS*	*NS*
Trust Technology	-0.20 -1.83 (†)	*N*	*NS*	*NS*
Trust Company	-0.27 -2.91 (*)	*NS*	*NS*	0.25 1.67 (†)
Regulation	*NS*	-0.20 -1.63 (†)	*NS*	*NS*
Public Input	0.24 1.75 (†)	*NS*	*NS*	*NS*
Public Debate	*NS*	0.27 1.71 (†)	-0.40 -3.59 (**)	-0.24 -1.51 (†)
Gender	*NS*	-0.17 -1.62 (†)	*NS*	*NS*
Education	*NS*	*NS*	0.22 1.94 (*)	*NS*
Discipline	*NS*	*NS*	-0.36 -3.45 (**)	*NS*

Coding used for dependent variables indicated in Table 4.1 and 4.4.
[1]*NS*: non-significant and significant at †$p < 0.10$; *$p < 0.05$; **$p < 0.001$; *** $p< 0.0005$.

B. Environmental risks

Both the public and experts from Canada who were critical of NT and its implications for the environment (factor 1) were supportive of regulation ($\beta = 0.16$, $\beta = 0.36$) and distrusted scientists ($\beta = - 0.29$, $\beta = - 0.15$). Experts further valued public debate ($\beta = 0.34$), and tended to be older ($\beta = 0.24$), single ($\beta = - 0.12$), to be financially worse off ($\beta = - 0.18$), and to specialize

in engineering and the life sciences (β = - 0.16). Public respondents from Canada further trusted technology (β = 0.21), were supportive of nano industries (β = 0.35), and tended to be male (β = - 0.22). Those experts from Korea, like their Canadian counterparts, were highly supportive of public debate (β = 0.44).

The role of independent variables in shaping expert and public attitudes to those who saw environmental benefits associated with NT was also examined (factor 2). Both public and expert proponents from Canada questioned any social impacts (β = - 0.38, β = - 0.28). Canadian experts trusted science (β = 0.20), were unsupportive of regulation (β = - 0.22) and public input (β = - 0.26), but supported public debate (β = 0.25). The public proponents from Canada distrusted companies (β = - 0.14), were less likely to support increase accountability of nano-industries (β = - 0.15), were more highly educated (β = 0.24), and were more likely to be male (β = - 0.12), whereas Korean experts trusted science (β = 0.61), were less interested in public debate (β = - 0.32), and tended to be married. Those proponents from the Korean public were less interested in public opinion (β = - 0.28) and tended to be educated (β = 0. 28). When groups across both countries were compared experts from Canada and Korea were both likely to trust science. Experts from Canada valued public debate whereas those from Korea did not (Table 4.9).

Table 4.9. Summary of multiple regression analysis examining the role of independent variables in shaping attitudes towards NT and the environment for the public and experts in Canada and South Korea

Variable + Factor	ENVIRONMENTAL RISKS			
	Canada		S. Korea	
	Public (n=126)	Expert (n=104)	Public (n=77)	Expert (n=66)
	Beta t value	Beta t value	Beta t value	Beta t value
F 1: Possible Solutions				
Trust Scientist	-0.29 -2.88 (*)	-0.15 -1.88 (†)	*NS*	*NS*
Trust Technology	0.21 1.93 (*)	*NS*	*NS*	*NS*
Nano-industries	0.35 3.67 (***)	*NS*	*NS*	*NS*
Regulation	0.16 1.66 (†)	0.36 4.05 (***)	*NS*	*NS*
Public Debate	*NS*[1]	0.34 2.98 (*)	*NS*	0.44 3.03 (*)
Gender	-0.22 -2.63 (†)	*NS*	*NS*	*NS*
Age	*NS*	0.24 2.68 (*)	*NS*	*NS*
Discipline	*NS*	-0.16 -1.83 (†)	*NS*	*NS*
Financial Wellbeing	*NS*	-0.18 -1.92 (*)	*NS*	*NS*
Marriage Status	*NS*	-0.12 -1.59 (†)	*NS*	*NS*
F2: Env- Issues				
Trust Science	*NS*	0.20 1.44 (†)	*NS*	0.61 2.41 (*)
Trust Company	-0.14 -1.46 (†)	*NS*		
Nano-indusries	-0.15 -1.54 (†)	*NS*	*NS*	*NS*
Regulation		-0.22 -1.75 (†)	*NS*	*NS*
Social Impact	-0.38 -4.18 (***)	-0.28 -2.28 (*)	*NS*	*NS*
Public Input	*NS*	-0.26 -1.76 (†)	*NS*	*NS*
Public Debate	*NS*	0.25 -1.58 (†)	*NS*	-0.32 -2.07 (*)
Public Opinion	*NS*	*NS*	-0.28 -1.78 (†)	*NS*
Gender	-0.12 -1.36 (†)	*NS*	*NS*	*NS*
Education	0.24 2.64 (*)	*NS*	0.28 2.00 (*)	*NS*
Marriage Status	*NS*	*NS*	*NS*	-0.36 -1.70 (†)

Coding used for dependent variables indicated in Table 4.1 and 4.4.
[1]*NS*: non-significant and significant at †$p < 0.10$; *$p < 0.05$; **$p < 0.001$; *** $p< 0.0005$.

4.6. Expert attitudes to the risks from Canada and South Korea

Respondents to the questionnaire were classified as experts if they were at least somewhat knowledgeable about NT (105 or 43% in Canada vs. 66 or 39% in Korea). They generally had very positive attitudes towards NT. They at least somewhat agreed (41% vs. 80%) that "nanoproducts would be higher in quality than conventional products" compared to the public (0% in Canada vs. 54% in Korea), especially with respect to the public from Canada who were strongly negative (64% vs. 8%) and were neutral or did not know (36% vs. 35%). Interviews

with experts provided greater detail on attitudes towards risks associated with nanotechnology and nanomaterials on products. Those from both Canada and Korea indicated that perceived risks could be best addressed, in decreasing order of importance, by an increase in research, regulation, and more effective communication with the public (Table 4.10).

1) Increased research on potential risks

The primary priority for mitigating NT-associated risks that was identified by experts was (perhaps predictably) more research, this accounting for most of the open-ended responses to risks associated with nanotechnology (46%) and nanomaterials in products (37%). In descending order of frequency, these comments referred to the need for better understanding and classification of the behavior nanomaterials, appropriate tests for safety, and more impact assessment (Table 4.10).

> *"Risk research of any risks should be conducted and funded by governments as they fund the development of nanotechnology and nanoproducts."*
> *(Academy -#888, Korea)*

Some indicated that risk regulations this early in the development of the technology might act as an impediment and undermine a newly emerging industry with tremendous potential.

> *"It is too much early to discuss regulatory policy regarding risks surrounding NT"*
> *(Academy-#887, Korea)*

Yet, others indicated that it may be premature to release some nanoproducts on the market for which there were inadequate risk data.

> *"Selling silver containing nano-washing detergents etc would be irresponsible if the risks are not known and cannot be communicated to the consumer or even be used to verify the safety of those products" (Government-#864, Korea)*

Indeed, some thought all nanoproducts should be evaluated.

> *"All* [NT] *products used in industry should be subject to environmental assessment because products applied in nanomaterials have already been introduced."*
> *(#868, Korea)*

Others suggested limiting the wide-scale availability of nanoproducts

> *"It would be a better approach to limit the use of the technology by industry in order to minimize the possibility of contamination and health damage." (Industry-#870, Korea)*

Others indicated that the industry was developing too quickly in the absence of risk data, and that this growth should be curtailed.

> *"Cut back on the production/research/legalization* [of nanoproducts]."
> *(Academy-# 891, Canada)*

2) Increased Risk Regulation

An increased emphasis on regulation of NT was also brought up frequently by experts, especially in Korea (27% for NT and 34% for nanomaterials) (Table 4.8). It was much more likely that respondents felt that there should be an increased accountability and responsibility of companies and researchers for nanomaterials in products (16%) that NT as a whole (1%). Of these responses, NT-specific regulations and labeling were commonly referred to and that the industry largely self-regulates any potential risks was criticized by some.

> *"The conventional system of self regulation by industry which gives responsibility to electronic and plastics companies would not work at all because the companies would simply cover up their mistakes. Of course, it could be claimed that further research and development could develop progressively better materials and products, but this is idealistic" (Industry-#870, Korea)*

In the absence of adequate regulations, others indicated that industry should ultimately be responsible for any mishaps.

> *"The regulatory system needs to be science-based, but at the same time one must apply the precautionary principle. The onus should be on the producer, not the consumer, to provide information on risks and to pay for any problems." (Academy-# 891, Canada)*

A few felt that desirable changes could be achieved by adapting existing regulatory frameworks.

"I think existing regulations can be used; it is not necessary to introduce new regulations specific to nanotechnology." (Industry-#868, Korea)

Some indicated that these regulatory standards should be established nationally by governments.

"Governments can help reduce any consumer concerns by establishing their own regulations rather than following international regulatory standards and systems." (Academy-#974, Korea)

In contrast, others felt that wide reaching international regulations would be useful.

"Nano technology must first tested in OECD developed countries before we test it in developing countries. The UN must also play a role in this initiative, especially regarding private sector investment." (Banker-#510, Canada)

Labeling was seen as desirable by most experts from Canada and, especially, Korea whom at least somewhat agreed (73% vs. 93%) that "all nanoproducts must be clearly labeled as containing nanomaterials." Most (85% vs. 86%) further thought that "the safety of each nanoproducts should be evaluated on a case-by case basis."

"Any risk should be identified on the label of the product - and then let the consumer chooses."(Academy-#856, Korea)

3) Improved effective communication

Finally, the need for more effective communication with the broader public was identified by many experts (27% for NT and 29% for nanomaterials). The importance of encouraging public participation did not vary substantially between nanotechnology (8%) and nanomaterials in products (12%). Many felt that the resulting lack of information, in turn, contributed to consumer fears regarding NT.

> *"It may come from fear of new things. NT has more benefits but people might be concerned about the risks because of a lack of information."*
> *(Academy-#856, Korea)*

Some felt that these fears were further aggravated by the bias of most criticisms of NT.

> *"There is much non-objective concern from those with political agendas far removed from technology assessment. Public education and advocacy from more objective and 'sober' sources are required." (Academy-# 892, Canada)*

Strategies for achieving better communication, in descending frequency, included an increase in the availability and quality of information, the sharing of verified information on risks, and encouraging public involvement in decision-making (Table 4.10).

> *"Because of the absence of information and the importance of communication with the public, the public should participate in decision-making regarding the*

introduction of nanotechnology and nanoproducts." (Government-#863, Korea)

Most experts felt that this communication should be science-based and many felt that scientists should be actively involved in this process.

"Education of the public is important; it is the responsibility of scientists to both carry out research to investigate the risks of NT as well as to educate the public about the real issues."(Academic-#420, Canada)

Table 4.10. Summary of possible solutions of the potential risks associated with nanotechnology and nanomaterials on products from experts in Canada (n=4) and South Korea (n=32)

1. How to mitigate perceived risks associated with nanotechnology?
Research (46%) 1. Description and classify of behavior of nanomaterials (28%) 2. Appropriate data and develop system safety test (14%)? 3. Increase investment for safety assessment (4%) **Regulation (27%)** 4. Develop further regulation (16%) 5. Implement labeling (10%) 6. Increase accountability and responsibility of companies and researchers (1%) **Communication (27%)** 7. Improve availability and quality of information for public (11%) 8. Share verified information on risks (8%) 9. Encourage public participation (8%)
2. How to reduce perceived risks associated with nanomaterials in products?
Research (37%) 1. Systematically evaluate risks through research (26%) 2. Create expert body from government, expert, and consumer (8%) 3. Establish national databases on the safety of nanomaterials (3%) **Regulation (34%)** 4. Increase accountability of companies, researchers, and government (16%) 5. Implement governmental policy and introduce technology (12%) 6. Implement labeling (6%) **Communication (29%)** 7. Improve information for public (12%) 8. Share of verified information on risks (12%) 9. Encourage public participation (5%)

5. DISCUSSION

Excitement regarding NT has increased as nanoproducts make their way onto the marketplace. However, there is a growing concern that risks associated with these products have not been adequately evaluated. This study was designed to compare attitudes towards human health and environmental risks associated with nanotechnology and nanomaterials in Canada and Korea, and to compare the attitudes of experts and the general public in both countries. Many risk perception studies emphasize that public concern may not stem from fear of emerging technologies themselves (e.g. Douglas, 1985; Macoubrie, 2005; Short, 1984; Tesh, 2000) but rather from lack of knowledge, social context, and poor communication surrounding these technologies (Cobb and Macoubrie, 2004; Small Talk, 2006). This study found substantial variation in attitudes towards potential human health and environmental risks. Differences were noted not only between the two countries, but also between the public and experts.

Awareness of Potential Human Health and Environmental Risks

Recent research methods related to the socio-cultural aspects of NT are beginning to incorporate a wider range of variables in order to better understand consumer attitudes towards new technologies (Lee *et al.*, 2005; McCluskey *et al.,* 2004; Slimak and Dietz, 2006).

In these analyses, over 20 independent variables were incorporated which were categorized as trust, reflectivity, and demographics. These results suggest that these variables play important roles in understanding attitudes regarding any human health and environmental risks associated with NT. These outcomes show the importance of balancing a wide range of factors that more fully reflect the socio-cultural characteristics of the respondents and help us better understand why people vary in their trust in and concern regarding NT. This understanding may, in turn, help reduce public fears surrounding any emerging technology. A comparison of

public and expert perceptions between countries is an important step in understanding why these attitudes might vary within and among countries.

Indeed, a large number of respondents from both countries (49% in Canada vs. 47% in Korea) at least somewhat agreed that they were "worried about the risks associated with NT." Overall, Canadians who trusted science and governments were also more interested in regulation and public debate. In contrast, Koreans who trusted scientists, technology, and industry were more likely to be concerned about the accountability of nano-industries, potential social impacts, public debate in decision-making.

Although respondents were generally much more concerned about human health risks than environmental risks, their attitudes toward possible forms of risk reduction (factor 1) and any health and environmental benefits of NT (factor 2) varied, especially between the public and experts. Predictably, if respondents had trust in science and technology, they were then unlikely to have concerns about human health and environment risks associated with the development and application of NT. Although the public was generally more concerned about these risks than experts, it is important to note was also a great diversity in public attitudes around these risks.

Socio-cultural Reflectivity on the Potential Risks

Any attempts to address the risk issues of emerging technologies must recognize the broader perspectives and socio-cultural backgrounds reflected in our increasingly globalized world (Moon and Balasubramanian, 2004). South Korea is located adjacent to North Korea, which is widely known to possess nuclear weapons and which has had diplomatic tensions with South Korea among many other nations. This may help explain why South Koreans ranked risks arising from nuclear power higher than Canadians, as they would have been more exposed to warnings

about the threats of nuclear weapons. There were high levels of concern about the avian flu and global warming in both countries. This may reflect the intense media coverage of the avian flu in Asia, Europe, and North America, and the linking of global warming to recent natural disasters in the US and southern Asia. It may also reflect the increasingly accepted view that these issues have become worldwide problems. Although consumers ranked NT among the lowest of health and environmental risks, this does not mean they did not recognize any NT-associated risks, but rather reflects the over-preponderance of other risks that confront our increasingly interconnected world. Indeed, many respondents still indicated substantial concerns over the technology.

As with many risk perception studies regarding GM foods and NT, public attitudes were associated with trust in experts and governments; regulations; communication; awareness of technology as a whole; and socio-demographic characteristics (e.g. Moon and Balasubramanian, 2004; Siegrist *et al.,* 2007). Of the twenty experimental variables used in this research, we found that regulations were highly valued by most respondents in both countries and, especially those who saw substantial human health and environment risks. In contrast, trust in scientists and companies were strongly associated with those who saw little NT-associated risk. Interestingly, the usefulness of public debate was highly valued by those concerned about and wanting to regulate possible risks (factor 1) and those that were unconcerned about any risks (factor 2), although perhaps for different reasons. Opponents likely want to have better input in regulation whereas proponents recognize that public acceptance is key if this industry is to continue to develop (Kahan *et al.,* 2008). Few respondents indicated that any human health or environmental risks could be effectively regulated by the nano-industry itself, as currently occurs in both Canada and Korea (Rejeski, 2006; Siegriest, 2008). However, it is also important to note that respondents from both countries were little aware of engagement and communication in

decision-making, especially regard nal research on any human health or erat is more targeted and experimental in nature exist between the two countries, and also thin those countries.

Of these independent variable: explanatory power (p<0.0005) to uncluding gender, education, discipline, marriss important (p<0.001 to p<0.1). Reflaen are generally more accepting of new te 006), male respondents from Canada were less especially the public, whereas those from Korks. Lack of concern about health risks was esp nd the life sciences, in contrast to those that h sciences and humanities, who were generall Although respondents that had backgrounds ily emphasized the benefits associated a recognition that regulation could pl tal risks increased with education levels as a

It is generally recognized that ligiosity (e.g. Scheufele *et al*, 2008). Howevof NT were more likely to be religious. Astents would be more concerned about ec ndings

ıs. There were high levels of concern about the a
This may reflect the intense media coverage of th
and the linking of global warming to recent natu
lso reflect the increasingly accepted view that th
Although consumers ranked NT among the low
not mean they did not recognize any NT-associat
ıce of other risks that confront our increasingly i
till indicated substantial concerns over the techn
studies regarding GM foods and NT, public attit
governments; regulations; communication; awa
emographic characteristics (e.g. Moon and Bala
twenty experimental variables used in this resear
by most respondents in both countries and, espe
and environment risks. In contrast, trust in scient
l with those who saw little NT-associated risk. I
highly valued by those concerned about and wa
d those that were unconcerned about any risks (f
ons. Opponents likely want to have better input i
public acceptance is key if this industry is to con
espondents indicated that any human health or e
by the nano-industry itself, as currently occurs i
Siegriest, 2008). However, it is also important to
re little aware of engagement and communicatic

showed that Canadian experts who supported the mitigation of any human health and environmental risks (factor 1) were likely to be older.

Management of the Potential Risks

It is increasingly recognized that the public acceptance of NT is central to the continued development and future of this industry and that it is important to anticipate and manage any public concerns. Experts in this study identified three key priorities in achieving the public acceptance of NT: increased independent risk research, adequate regulation, and more effective communication with the public. Research on potential human health and environmental risks and any social implications of NT currently accounts for less than 10% of the total investment in the industry in any given year (Roco, 2008). Experts from both countries indicated that this investment in research should be doubled (19% and. 18% of all investment in Canada and Korea, respectively). It was further indicated that most of this investment should be used to fund research on health risks (41% and 39%, respectively), followed by environmental risks (38% and 39%, respectively) and finally any social and ethical implications (21% and 21%, respectively) of NT. Many experts recommended that risk research associated with nanotechnology and especially with nanomaterials should be conducted independent of the industry and should funded to a greater extent by governments, in part so that any potential risks might be evaluated at "arms-length" from the nano-industry itself.

Moreover, most experts in Canada and Korea (69% and 52%, respectively) at least somewhat agreed that "risks with NT can be meaningfully reduced by regulation." Only a minority (19% and 17%, respectively), were at least somewhat satisfied with existing regulation of NT, although many others were also neutral (17% and 18%, respectively). These concerns

demonstrate a perceived failure of the current regulations to protect against potential risks associated with nanotechnology and nanomaterials. While it may also reflect a lack of familiarity with the existing regulations, it does indicate that many experts see the inadequacy of the current regulatory framework in each country as an issue that needs to be addressed by decision-makers. Most experts felt that these regulations should be science-based. Although they generally supported the labeling of nanoproducts experts, ostensibly allowing consumer to choose whether or not they partake in this technology, only half (54% and 56%, respectively) supported public participation in decision-making regarding NT. Unsurprisingly, some experts indicated that the conventional system of self-regulation by industry, which gives the responsibility to electronic and plastics companies with NT applications, would be ineffective as many might downplay any risks because of their tremendous investment in the technology.

An increase in the effectiveness of communication with the public was also identified as an important priority. This might be achieved by improving public education, by encouraging public participation surrounding the technology, by providing appropriate (i.e. science-based) information to public, and by sharing verified information. Although these suggestions focused on communication with the broader public, they would likely benefit experts as well, especially in Canada. Only 49% and 73% of experts in Canada and Korea, respectively, had taken any courses involving NT. This and the general absence of risk data suggests that they too may be lacking insights into the broader health and environmental risks associated with NT. In the absence of adequate education for both experts and the public, many experts (52% and. 56%, respectively) at least somewhat agreed with the statement that "social, environmental, and health implications of NT should be emphasized in the formal training of people working in this field", although some were neutral (19% and 21%, respectively). These outcomes thus suggest that,

improving education surrounding this industry should target not only the public but also experts. In this way, balanced approaches to both risks and benefits will be achieved, this essential if the important NT industry is to thrive in the future.

REFERENCES

Albrecht, M. A., Evans C. W., and Raston C. L. (2006). Green chemistry and health implications of nanoparticles. *Green Chemistry*, 8, 417-432.

Besley, J. C., Kramer, V. L., and Priest, S. H. (2008). Expert opinion on nanotechnology: Risks, benefits, and regulation. *Journal of Nanoparticle Research*, 10, 549-558.

Biel, A. and Dahlstrand, U. (1995). Risk perception and the location of a repository for spent nuclear fuel. *Scandinavian Journal of Psychology*, 36, 25-36.

Bowman, D. M. and Hodge, G. A. (2007). A small matter of regulation: An international review of nanotechnology regulation. The Columbia Science and Technology Law Review. Available at: http://www.stlr.org/html/volume8/bowman.pdf

Boyce, N. (2007). Safety of nano-cosmetics questioned. *National Public Radio*. Available at: http://www.npr.org/templates/story/story.php?storyId=5257306

Burri, R. V. (2007). Deliberating risks under uncertainty: Experience, trust, and attitudes in a Swiss nanotechnology stakeholder discussion group. *Nanoethics*, 1, 143-154.

Cobb, M. D. and Macoubrie, J. (2004). Public perceptions about nanotechnology: Risks, benefits and trust. *Journal of Nanoparticles Research,* 6, 395-405.

Cohen, B. L. (1985). Criteria for technology acceptability. *Risk Analysis*, 5, 1-2.

Commonwealth of Australia. (2005). Senate Community Affairs reference committee-inquiry into workplace exposure to toxic dust-Terms of reference. Canberra, Australia: Commonwealth Government. Available at: http://www.aph.gov.au/Senate/committee/clac_ctte/completed_inquiries/2004-07/toxic_dust/report/c01.htm

Cook, A. J. and Fairweather, J. R. (2005). Nanotechnology - ethical and social issues: results from New Zealand focus groups. Research Report No. 281. Canterbury, New Zealand: Lincoln University.
Available at: http://www.lincoln.ac.nz/story_images/1330_rr281_s4140.pdf

Council for Science and Technology. (2005). Policy through dialogue: informing policies based on science and technology. London: Council for Science and Technology.
Available at: http://www2.cst.gov.uk/cst/reports/files/policy-through-dialogue/report.pdf

Creswell, J. W. (2003). Research design: Qualitative, quantitative, and mixed methods approaches (2nd Edition). London: Sage.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297-334.

Cronin, K. E. (2004). From biotech to nanotech-Enhancing deliberative processes for science and technology innovation. Victoria University of Wellington, Wellington, New Zealand. Available at: http://www.engagingcommunities2005.org/abstracts/Cronin-Karen-final.pdf

Doubleday, R. (2007). Risk, public engagement and reflexivity: Alternative framing of the public dimensions of nanotechnology. *Health, Risk, and Society*, 9, 211-227.

Douglas, M. (1985). Risk acceptability according to the social sciences. Russell Sage Foundation, New York.

ElAmin, A. (2006). Nanotech database compiles consumer items on the market. Available at: http://www.foodproductiondaily.com/Supply-Chain/Nanotech-database-compiles-consumer-items-on-the-market

ETC Group. (2003). The big down: Atomtech-tehnologies converging at the nanoscale. ETC Group, Winnipeg, Manitoba, Canada. Available at: http://www.etcgroup.org/upload/publication/171/01/thebigdown.pdf

Fife-Schaw, C. and Rowe, G. (1996). Public perceptions of everyday food hazards: A psychometric study. *Risk Analysis*, 16, 487-500.

Friends of the Earth. (2006). Manometarials, sunscreens and cosmetics: Small ingredients, big risks, report, -32. Available at: http://nano.foe.org.au/node/100

Grove-White, R., Kearens M., Miller P., Macnaghten P., Wilsdon, J., and Wynne, B. (2004). Bio-to-Nano?: Learning the lessons, interrogating the comparison. Institute for Environment, Philosophy and Public Policy, Lancaster University and Demos. Available at: http://www.nanoandsociety.com/ourlibrary/documents/bio+to+nano.pdf

Handy, R. D. and Shaw, B. J. (2007). Toxic effects of nanoparticles and nanomaterials: Implications for public health, risk assessment and the public perception of nanotechnology. *Health, Risk, and Society*, 9, 125-144.

Hannah, W. and Thompson, P. B. (2008). Nanotechnology, risk and the environment: A review. *Journal of Environmental Monitoring*, 10, 291-300.

Hatcher, L. (1994). A step-by-step approach to using the SAS system for factor analysis and structural equation modeling (3rd Edition). Cary, NC: SAS Institute Inc.

Helland, A. (2004). Nanoparticles: A closer look at the risks to human health and the Environment. Master of Science in Environmental Management and Policy (Thesis), Lund, Sweden.

Hoet, P. H. M., Bruske-Hohlfeld I., and Salata O. V. (2004). Nanoparticles-known and unknown health risks. *Journal of Nanotechnology,* 2, 1-19.

Jackson, R., Barbagallo, F., and Haste, H. (2005). Strengths of public dialogue on science-related issues. *Critical Review of International Social and Political Philosophy*, 8, 349-358.

Johnson, L. A. (2007). Nano-based products starting to have consumer impact, USATODAYs. Com. Available at: http://www.usatoday.com/tech/news/nano/2004-11-08-nano-on-the-move_x.htm

Kanarek, M. S. (2007). Nanomaterial health effects-part 3: Conclusion-Hazardous issues and the precautionary principle. *Wisconsin Medical Journal*, 106, 16-19.

Katao, K. (2006). Nanomaterials may call for a reconsideration of the present Japanese chemical regulatory system. *Clean Technology Environmental Policy*, 8, 251-259.

Kearnes, M, Macnaghten, P., and Wilson J. (2006). Governing at the nanoscale: People, policies and emerging technologies. Demos, London. Available at: http://www.demos.co.uk/files/governingatthenanoscale.pdf?1240939425

Kulve, H. T. (2006). Evolving repertoires: Nanotechnology in daily newspapers in the Netherlands. *Science as Culture*, 15, 367-382.

Kuzma, J. and VerHage, P. (2006). Nanotechnology in agriculture and food production. Washington, DC: Woodrow Wilson International Center for Scholars. Available at: http://www.nanotechproject.org/file_download/files/PEN4_AgFood.pdf

Lee, C. J., Scheufele, D. A., and Lewenstein, B. V. (2005). Public attitudes toward emerging technologies. *Science Communication,* 27, 240-266.

Leung, K. and Bond, M.H (1982). How American and Chinese reward task-related contributions: a preliminary study. *Psychologia*, 25, 2-9.

Levy, A. S., Choiniere, C. J., and Fein, S. B.(2008). Practice-specific risk perceptions and self-reported food safety practices. *Risk Analysis*, 28, 749-761.

McCluskey, J. J., Grimsrud, K. M., and Wahl, T. I. (2004). Comparison of consumer responses to genetically modified foods in Asia, North America, and Europe. *Regulating Agricultural Biotechnology: Economics and Policy*, Chapter 11, 227-240.

Macoubrie, J. (2005). Informed public perceptions of nanotechnology and trust in Government. Washington DC: Project on Emerging Nanotechnology. Available at: http://www.wilsoncenter.org/news/docs/macoubriereport.pdf

Madison. (2005). Report of the Madison area citizen consensus conference on nanotechnology. Available at: http://www.nanocafes.org/files/consensus_conference_report.pdf

Marris, C., Langford, I. H., and O'Riordan, T. (1998). A quantitative test of the cultural theory of risk perceptions: Comparison with the psychometric paradigm. *Risk Analysis*, 18, 635-647.

Maxwell, J. A. (2005). Qualitative research design: An interactive approach. Sage Publications, Thousand Oaks, CA.

Mehta, M. D. (2004). From Biotechnology and nanotechnology: What can we learn from earlier technology? *Technology and Society,* 24, 34-39.

Michelson, E. S. and Rejeski, D. (2006). Falling through the cracks? Public perception, risk, and the oversight of emerging nanotechnologies. *Technology and Society*, 1-17. Available at: http://ieeexplore.ieee.org/stamp/stamp.jsptp=&arnumber=4375890&isnumber=4375875

Miller, G. and Senjen, K. (2008). Out of the laboratory and on to our plates: Nanotechnology in food and agriculture. Friends of the Earth, Australia, Europe and USA, March. Available at: http://www.foe.org/pdf/nano_food.pdf

Moon, W. and Balasubramanian, S. K. (2004). Public attitudes toward agrobiotechnology : The mediating role of risk perceptions on the impact of trust, awareness, and outrage. *Review of Agricultural Economics*, 26, 186-208.

Nanologue. (2005). Nanologue-Facilitating dialogue between research, business and society. Paper presented at EuroNanoForum, Edinburgh, Scotland.

Powell, M. C. and Kanarek, M. S. (2006). Nanomaterial health effects-part 1: Background and current knowledge. *Wisconsin Medical Journal*, 105, 16-20.

Powell, M. C. and Kanarek, M. S. (2006). Nanomaterial health effects-part 2: Uncertainties and recommendations for the future. *Wisconsin Medical Journal*, 105, 18-23.

Priest, S. H. (2006). The North American opinion climate for nanotechnology and its products: Opportunities and challenges. *Journal of Nanoparticle Research*, 8, 563-568.

Priest, S. H. (1995). Information equity, public understanding of science and the biotechnology debate. *Journal of Communication*, 45, 39-54.

Rejeski, D. (2006). FDA and nanotechnology: Public perceptions matter. Project on Emerging Nanotechnologies, 1-11. Available at: http://www.nanotechproject.org/file_download/files/RejeskiFDA.pdf

Robbins, R. (2001). Overburdening risk: Policy frameworks and the public uptake of gene technology debate. *Public Understanding of Science*, 10, 19-36.

Roco, M. C. (2008). National nanotechnology initiative FY 2009 budget & highlights.

Available at: http://www.nsf.gov/crssprgm/nano

Rogers-Hayden, T. and Pidgeon, N. (2006). Reflecting upon the UK's citizens' jury on nanotechnologies: NanoJury UK. *Nanotechnology Law & Business* (May/June), 167-178.

Roszek, B., de Jong, W. H., and Geertsma, R. E. (2005). Nanotechnology in medical applications: State-of-the-art in materials and devices. RIVM report. Available at: http://lamp.tu-graz.ac.at/~hadley/nanoscience/references/RIVM.pdf

Royal Society. (2004). Nanoscience and nanotechnologies: Opportunities and uncertainties. Royal Society and Royal Academy of Engineering, London. Available at: http://www.nanotec.org.uk/finalReport.htm

Sanguansri, P. and Augustin, M. A. (2006). Nanoscale materials development-a food industry perspectives. *Trends in Food Science and Technology*, 17, 547-556.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., and Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis*, 24, 1289-1299.

Scheufele, D.A., Corley, E. A., Shih, T., Dalrymple, K. E., and Ho, S. S. (2008). Religious beliefs and public attitudes toward nanotechnology in Europe and the United Stated. *Nature Nanotechnology,* 4, 91-94.

Sharpe, M (2006). Small wonders, big future: The development of environmental nanotechnology. *Journal of Environmental Monitoring,* 8, 235-239.

Short, Jr., J. F. (1984). The social fabric at risk: toward the social transformation of risk analysis. *American Sociological Review* 49, 711-725.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis*, 20, 195–204.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science and Technology.* 11, 603-608.

Siegrist, M., Keller, C., Kastenholz, H., Frey, S., and Wiek, A. (2007). Lay people's and experts' perception of nanotechnology hazards. *Risk Analysis*, 27, 59-69.

Slimak, M. W. and Dietz, T. (2006). Personal values, beliefs, and ecological risk perception. *Risk Analysis,* 26, 1689-1705.

Slovic, P. (1987). Perception of risk. *Science,* 236, 280-285.

Small Talk. (2006). Small talk: Project report (London: Think-Lab)

Sparks, P. and Shepherd, R. (1994). Public perceptions of the potential hazards associated with

food production and food consumption: An empirical study. *Risk Analysis*, 14, 799-806.

Swiss, Re. (2004). Nanotechnology: Small matter, many unknown. Swiss Reinsurance Company, Zurich. Available at: http://www.swissre.com/INTERNET/pwsfilpr.nsf/vwFilebyIDKEYLu/ULUR-5YNGET/$FILE/Publ04_Nanotech_en.pdf

TA-Swiss (2006). Public reactions to nanotechnology in Switzerland. Report on publifocus discussion forum "nanotechnology, health, and the environment." TA-P 8/2006. Centre for Technology Assessment at the Swiss Science and Technology Council, Bern

Taylor-Gooby, P. and Zinn, J. O. (2006). Current directions in risk research: new developments in psychology & sociology. *Risk Analysis*, 26, 397-411.

Tesh, S. N. (2000). Uncertain hazards: Environmental activists and scientific proof. Ithaca, NY: Cornell University Press.

Thomas, T., Thomas K., Sadrieh, N., Savage, N., Adair, P., and Bronaugh, R. (2006). Research strategies for safety evaluation of nanomaterials, Part VII: Evaluating consumer exposure to nanoscale materials. *Toxicological Sciences*, 91, 14-19.

Tsuji, J. S., Maynard A. D., Howard, P. C., James, J. T., Lam C., Warheit, D. B., and Santamaria, A. B. (2006). Research strategies for safety evaluation of nanomaterials, Part IV: Risk assessment of nanoparticles. *Toxicological Sciences*, 89, 42-50.

Wilkinson, C., Allan, S., Anderson, A., and Petersen, A. (2007). From uncertainty to risk?: Scientific and news media portrayals of nanoparticles safety. *Journal of Health, Risk, and Society*, 9, 145-157.

Wood, S. (2005). Understanding the risks of the science of the small. A Report by the Jupiter Socially Responsible Investment (SRI) and Governance Team, October.

CHAPTER 5: Final Discussion

1. SUMMARY

Nanotechnology (NT) is an emerging form of technology that is generating much excitement with scientists, industry, governments, and indeed consumers around the world, and is rapidly progressing with respect to its production, distribution, and marketing. Although nanoproducts are fast being developed and released on markets in both Canada and Korea, few studies have adequately explored the perceptions of this new technology in either country, much less compared how they vary between the two. There have been some studies examining public and expert perceptions of NT in North America and European countries; however, none to my knowledge have compared public and expert attitudes to NT between North America and Asia.

2. RESEARCH OUTCOMES

Overall, I found that a substantial knowledge gap exists regarding NT with respect to the public. Most respondents from Canada and especially Korea (84% vs. 94%) had heard of NT but relatively few (24% vs.16%) indicated they were knowledgeable of the technology. Despite a wide variety of opinions, most respondents were highly optimistic about the technology, especially those from Korea. Indeed, little difference existed between the two countries regarding expertise of NT, trust in technology, attitudes towards the environment, and concern regarding public input. Generally, respondents from both countries were most excited about the potential of NT for human health, especially in Canada, followed by environmental benefits. I was personally surprised that the widely media-promoted human convenience was ranked last in importance. This optimism was especially true for Canadian experts who were largely proponents of NT; had greater trust in science, scientists, and technology; and who were less likely to support greater

participation in decision-making regarding NT. Although much more likely to be knowledgeable of NT than opponents, Canadian experts were also much less likely to be concerned about any risks.

Indeed, those that are critical of NT and that have communitarian and egalitarian world views will use any information regarding NT to highlight the attendant risks whereas those with hierarchical and individualist views will inevitably highlight any benefits of the technology (Kahan *et al.*, 2008). This relationship between favorable attitudes and familiarity further reflects our difficulty in identifying and involving experts working for NGOs that are critical of the industry as well as our difficulty in identifying experts in NT that have training in disciplines others than the life sciences and engineering.

Respondents sorted out into three groups: opponents that were highly critical of NT, proponents that were highly supportive, and, a third group, conditional proponents, that seemed to evaluate benefits against any potential risks before making any decisions. Opponents to NT from Canada were more likely to be women and were less likely to be knowledgeable of NT, and, for public opponents, were less likely to have high levels of formal education. Indeed, public respondents as a whole that were male were less likely to be critical than their female counterparts, this reflected in both countries. Experts in NT, which generally had more favorable attitudes towards NT, were more likely to be men and were more likely to be trained in the sciences, especially engineering and the life sciences.

While Korean conditional proponents of NT were likely to trust scientists, they were also concerned about human health implications. Korean experts that were conditional proponents had trust in scientists but were less likely to be concerned about environment whereas their Canadian counterparts were less likely to be concerned about any social impacts. Overall,

conditional proponents were much more concerned about human health risks than environmental risks, especially those who specialized in social sciences and humanities than in engineering and the life sciences.

Of the independent variables, that shaped attitudes towards NT, some were very important for both Canada and Korea, including concern regarding social impacts and the environment, public input, and trust in scientist and technology. Others that were of less statistical importance but that were still meaningful, included levels of formal education, specialization in education, gender, age, religion, marriage status, and financial wellbeing.

Regarding perceptions of health and environmental risks associated with NT, almost half of the respondents from each country (49% in Canada vs. 47% in Korea) were at least somewhat worried about the risks associated with NT. Overall, Canadians who were trusting of science and government were more interested in regulation, public input, and public consultation whereas Koreans who were trusting of scientists, technology, and industry were more likely to value increasing responsibility of nano-industries, social impact, public debate, and public opinion in decision-making. Although respondents were much more concerned about NT-associated risks to human health than the environment, ways that these risks might be mitigated also varied, especially between the public and experts. Interestingly, only experts were interested in public debate, but they were also generally against public input. Although many respondents indicated they were concerned about NT-associated risks, these ultimately ranked much lower than other risks that threaten human health and the environment. Korean respondents were thus much more concerned about risks associated with nuclear power and respondents from both countries were greatly concerned about avian influenza and global warming.

Interviews with experts provided greater and richer detail on attitudes towards risks

associated with nanotechnology and nanomaterials contained in products. Respondents from both Canada and Korea indicated that potential risks could be best addressed, in decreasing order of importance, by increases in research, regulation, and more effective communication with the public. There is still very little independent research that is conducted regarding NT especially regarding any potential social implications. Although environmental and health risk research is growing, it still only accounts for under 8% of the investment for the National Nanotechnology Initiative (NNI) funding opportunities in the USA, 2009 (Roco, 2008), and very little of this supports independent social research regarding these issues.

Of the 20 independent variables that were examined, we found that nano-industries, regulation, and public debate were highly influential ($p<0.0005$) in shaping positive attitudes towards NT ($p<0.0005$) regarding human health and environment risks in both Canada and Korea. In contrast trust in scientists and companies and concern about potential social impacts were significantly associated ($p<0.0005$) with negative attitudes. With respect to demographic variables, expertise with NT was the most important ($p<0.0005$) in shaping attitudes, whereas gender, education, discipline, marriage status, financial wellbeing, and religion were less important ($p<0.001$, or $p<0.1$) but still meaningful.

Interestingly, the value of public input was identified as highly positive by those concerned about risks and ways of regulating these risks and as negative by those who identified with the benefits associated with NT. However, it is also important to note that there seemed to be little overall awareness in either country as to how the public might become better informed and involved in decision-making, especially with respect public opinion and public consultation. In comparison to other countries, especially in Europe (e.g., nanologues, nanojuries, and nanofora etc.), governments in Canada and Korea have done little to engage the wider public around NT.

This seems to be an especially critical priority, especially if we are to avoid repeating the mistakes around public opinion that have plagued biotechnology over the last 20 years. Although many small-group studies have been conducted to examine how the general public might contribute to decision-making regarding new technologies, these have yet to be implemented at national and international scales of decision-making.

That said, this study – like all studies – suffered from some shortcomings. Our approach to distinguish the public and expert group was to ask respondents to self identify their level of expertise about NT, assessed by the one Likert-scaled question: "I am knowledgeable about nanotechnology", whereas other studies use multiple questions to test the extent of the (inevitably science-based) knowledge (Besley *et al.*, 2008). However, these data were then triangulated with a broad range of other variables, including occupation, academic specialization, age, gender, and education level. Open ended responses from experts who were professors, researchers, post-graduate students or master students in Canada and Korea, indicated that some participants ultimately questioned their ability to respond to many of the quite specific questions regarding NT, and perhaps a sizeable proportion of the respondents, both lay and expert, might have re-evaluated their "state" of NT knowledge by the end of the survey. In retrospect, we might have at least asked respondents to self-identify their knowledge regarding NT a number of times throughout the questionnaire, especially at the end as opposed to the beginning of the instrument.

These difficulties were further reflected by some of the expert criticisms of the survey, most of whom had been trained in the life and engineering sciences. Many seemed to be antagonistic to the general nature of many of the NT-related questions, especially those that were Likert-scaled, as well as the focus on the environmental and societal implications of the technology,

perhaps because they are less well versed in these NT-associated health and environmental issues and regulatory frameworks than their own more specific areas of scientific research expertise. This may also help explain the relatively low response rates to the questionnaire of our researcher-identified experts compared to the public as a whole (10% vs. 50%). These concerns may also have been further reflected in our difficulty in recruiting experts from government and the nano-industry, especially in Canada.

Another shortcoming of this study reflects our dependence on convenience sampling in train stations and shopping malls as well as universities. Although this was mitigated by randomly selecting potential respondents at different times of the day, the resulting sample likely did not reflect the population as a whole as it selected for more mobile aspects of the population in each country. We further mitigated this as a problem by focusing most of the subsequent data analysis on the scores arising from the factor analysis rather than the raw data (Mehta, pers. comm.), but differences in mean responses to individual questions were still examined throughout the thesis. We further elected to stratify sample according to city, gender, age, university enrollment, and, to the degree possible, academic training. Although this facilitated subsequent analysis, it resulted in a higher proportion of university students and science-trained respondents than would have emerged from a random sample, thereby arguably limiting our ability to generalize these results to the population as a whole. Despite this attempt to identify respondents with expertise in NT, most of these experts were science-trained, worked in academia or industry, and were male, which further dichotomized the outcomes and resulted in most experts being supportive of NT, which in turn, arguably biased our results in favour of NT. Although there are growing numbers of scientists that are aligning themselves with non-governmental and activist environmental and health organizations (Hess, 2009), this critical voice has yet to be reflected in the relatively new

field of nanotechnology. These shortcomings would have been less of a concern in a strictly qualitative study where randomized sampling and large sample sizes are obviously of little concern (Creswell, 2003). A qualitative approach would also have allowed for us to more closely engage respondents and would have allowed us to use some experimental approaches and more detailed case studies. Regardless of these limitations, this study plays an important role in highlighting differences in risk perception between the public and experts regarding NT, and effectively explores the cultural contexts within which these distinctions occur.

3. IMPLICATIONS AND FUTURE DIRECTIONS

This study arguably provides much direction for future studies on public policy regarding nanotechnology in each country, and, indeed, the two societies as a whole. Most respondents in this study indicated that they lacked specific information regarding NT. They were also concerned about the uncertainty regarding NT-associated risks regarding human health and environment as well as regulation and safety. Consumers would benefit from better communication especially if it was perceived as independent and balanced in nature. Most media coverage focuses only on the positive implications of NT, these including the promise of nanotechnology and its solutions for key social issues (Faber, 2006).

Expert interviews identified a pressing need for research, adequate regulation, and more effective communication with the public. It is important that research from government, industry, and universities support and focus on investigating health and environmental implications of NT in order to alleviate public concerns. Additional social research is needed that might help identify reasons for the differences in attitudes that I observed. This would not only focus on differences between countries, but also between the public and experts within those countries, especially regarding the development of education and communication programs on NT-associated risks.

Although most experts in Canada and Korea (69% and 52%) at least somewhat agreed that "risks with NT can be meaningfully reduced by regulation", few experts (19% and 17%, respectively), agreed that existing regulations regarding NT were adequate. This demonstrates a perceived failure of the current regulations to protect against the potential risks associated with nanotechnology and nanomaterials. Moreover, these concerns might reflect a lack of familiarity with regulations, in turn due to a lack of information and lack of networking and communication among experts regarding these largely social and ethical issues. The outcomes of this study show that experts were less interested public consultation and public input in decision-making, and instead valued science-based outreach and decision-making as a solution to these concerns, as well as public debate to more effectively achieve these ends.

Yet, without meaningful and continued public consultation, it will be difficult to predict which applications are of concern and which are seen as meeting important societal needs (Prist, 2006). Public attitudes towards technology as a whole play an important role in determining lay attitudes towards specific applications such as NT. There was generally little support for self regulation by the NT industry and most respondents desired for governments to play a greater role in determining policies regarding NT. Indeed, more effective communication around potential benefits and risks would help mitigate future NT-associated concerns, especially regarding the food and health domains, which are most likely to become increasingly controversial in the future (Siegrist, 2008; Rejeski, 2006).

Some of the ways that communication with the public might be increased in effectiveness include improving public education by encouraging public participation, providing appropriate information to public, and the better sharing of verified information. These solutions would certainly be supported by the public, but would also be beneficial for experts, especially those

from Canada. Thus, only 49% and 73% of experts in Canada and Korea, respectively, had ever taken any courses that involved NT. Most of these courses as well as the lived experiences where scientists would otherwise develop their expertise, would likely have been scientific and technical in nature and few, if any, would have emphasized the importance of public attitudes and outreach. Yet, interestingly, just over half of these expert -scientists (52% vs. 56% in Canada and Korea, respectively) at least somewhat agreed that "social, environmental, and health implications of NT should be emphasized in the formal training of people working in this field." Improvements in the availability and diversity of educational opportunities surrounding NT should thus target not only the public but also experts. It is only through educational initiatives such as these, as well as corresponding increases in independent research and the development of meaningful risk regulation, that the impasses between opponents and proponents of NT, and for that matter other emerging forms of technology, will be bridged in the future.

REFERENCES

Creswell, J. W. (2003). Research design: Qualitative, quantitative, and mixed methods approaches (2nd Edition). Sage, London.

Faber, B. (2006). Popularizing nanoscience: the public rhetoric of nanotechnology, 1986–1999. *Technical Communication Quarterly*, 15, 141–169.

Kahan, D. M., Braman, D., Slovic, P., Gastil, J., and Cohen, G. (2008). Cultural cognition of the risks and benefits of nanotechnology. *Nature Nanotechnology*, 4, 87-90.

Hess, D. J. (2009). Alternative pathways in science and industry: Activism, innovation and the environment in an era of globalization. MIT Press, Cambridge.

Priest, S. H. (2006). The North American opinion climate for nanotechnology and its products: Opportunities and challenges. *Journal of Nanoparticle Research*, 8, 563-568.

Rejeski, D. (2006). FDA and nanotechnology: Public perceptions matter. Project on emerging nanotechnologies, 1-11. Available at: http://www.nanotechproject.org/file_download/files/RejeskiFDA.pdf

Roco, M. C. (2008). National nanotechnology initiative FY 2009 budget & highlights. Available at: http://www.nsf.gov/crssprgm/nano

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science and Technology,* 19, 603-608.

APPENDIX 1: Terminology

1. **Nanotechnology** refers to the manipulation of living and non-living matter at the level of the nanometer (nm), one billionth of a meter. It is at this scale that quantum physics takes over from classical physics and the properties of elements change character in novel and unpredictable ways.

2. **Benefits:** Something that promotes or enhances well-being for society, humans and/or the environment; an advantage.

3. **Perceived Risks:** Negative or unexpected consequences a consumer fears may occur as a result of making the wrong purchase decision.

4. **Objective Risks** is the actual losses for a sample for a given period.

5. **Nanomaterials** are materials with morphological features smaller than a one tenth of a micrometre in at least one dimension.

6. **Public:** Knowledge regarding NT according to responses from Canada and Korea to the question: "I am knowledgeable about Nanotechnology", which was measured with a seven-point Likert scale. Respondents self-determined their knowledge regarding NT and those indicating "strongly disagree" or "disagree" were then designated as the public (149 in Canada and 80 in Korea). These data were then triangulated with other variables, including a broad range of occupation, specialization, age, gender, and education level (some were highly educated but not in science-based disciplinary, but most of them were not highly educated).

7. **Expert:** Knowledge regarding NT according to responses from Canada and Korea to the question: "I am knowledgeable about Nanotechnology", which was measured with a seven-point Likert scale. Respondents self-determined their knowledge regarding NT and those indicating "strongly agree" or "agree" were then designated as experts (123 in

Canada and 74 in Korea). These data were then triangulated with other variables, including a broad range of occupation, specialization, age, gender, and education level (most of them who work at research laboratories in the field of nanotechnology were highly educated which were master's degree or more and in science-based disciplinary).

8. **Risk Communication:** The exchange of information about health or environmental risks among researchers, managers, the general public, news media, interest groups, and decision-makers etc.

9. **Hazard:** A hazard is a situation which poses a level of threat to life, health, property or environment. Most hazards are dormant or potential, with only a theoretical risk of harm, however, once a hazard becomes 'active', it can create an emergency situation.

10. **Risk Assessments** is an important first step in risk management. It is the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat. It consists of an objective evaluation of risk in which assumptions and uncertainties are clearly considered and presented

11. **Safety** is the state of being "safe", the condition of being protected against physical, social, spiritual, financial, political, emotional, occupational, psychological, educational or other types or consequences of failure, damage, error, accidents, harm or any other event which could be considered non-desirable.

12. **Costs:** The value of money that has been used up to produce something involving private, external, social, and psychic costs.

13. **Precautionary Principle** is a moral and political principle which states that if an action or policy might cause severe or irreversible harm to the public or to the environment, in the absence of a scientific consensus that harm would not ensue, the burden of proof falls on those who would advocate taking the action.

APPENDIX 2: Questionnaires

Please feel free to contact us if you have any questions about this research or want to see the questionnaires that we used:

- **Soon-Hee OH, M. Sc and M. Env.**
  Email: oosh21@hotmail.com

- **Stéphane McLachlan, Ph. D.**
  Email: mclachla@cc.umanitoba.ca

  CHR Faculty of Environment, Earth, and Resources, University of Manitoba,
  Winnipeg, Manitoba, Canada R3T 2N2
  Phone: 204-474-9316