Responsibility, Regulation and the Construction of Markets of Nanotechnologies in Food and Food Packaging: The Cases of Canada and India

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<td>American Chemical Society</td>
</tr>
<tr>
<td>AAFC</td>
<td>Agricultural and Agrifood Canada</td>
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<tr>
<td>AITC</td>
<td>Antimicrobial Compound Allyl Isothiocyanate</td>
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<tr>
<td>AOAC</td>
<td>Association of Analytical Communities</td>
</tr>
<tr>
<td>APCTT</td>
<td>Asian and Pacific Centre for Transfer of Technology</td>
</tr>
<tr>
<td>APEDA</td>
<td>Agricultural and Processed Food Products Export Development Authority</td>
</tr>
<tr>
<td>ARCI</td>
<td>International Advanced Research Centre for Power Metallurgy and New Materials</td>
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<td>BIAC</td>
<td>Business and Industry Advisory Committee</td>
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<tr>
<td>BIS</td>
<td>Bureau of Indian Standards</td>
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<tr>
<td>BRICS</td>
<td>Brazil, the Russian Federation, India, China and South Africa</td>
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<tr>
<td>BSE</td>
<td>Bovine spongiform encephalopathy</td>
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<td>BUND</td>
<td>Friends of the Earth Germany</td>
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<tr>
<td>CBEN</td>
<td>Center for Biological and Environmental Nanotechnology</td>
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<td>CCA</td>
<td>Council of Canadian Academies</td>
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<tr>
<td>CCMB</td>
<td>Centre for Cellular and Molecular Biology</td>
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<tr>
<td>CEPA</td>
<td>Comprehensive Economic Partnership Agreement</td>
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<td>CFI</td>
<td>Canada Foundation for Innovation</td>
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<td>European Environment Agency</td>
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<tr>
<td>EEB</td>
<td>European Environmental Bureau</td>
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<tr>
<td>EHS</td>
<td>Environment, Health and Safety</td>
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<tr>
<td>ELS</td>
<td>Ethical, Legal and Social</td>
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<tr>
<td>ELSA</td>
<td>Ethical, Legal and Social Aspects</td>
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<tr>
<td>ELSI</td>
<td>Ethical, Legal and Social Issues</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>EPFL</td>
<td>Swiss Federal Institute of Technology</td>
</tr>
<tr>
<td>EPR</td>
<td>Extended Producer Responsibility</td>
</tr>
<tr>
<td>EPSRC</td>
<td>The Engineering and Physical Sciences Research Council</td>
</tr>
<tr>
<td>ESFA</td>
<td>European Food Safety Authority</td>
</tr>
<tr>
<td>ETC</td>
<td>Action Group on Erosion, Technology and Concentration</td>
</tr>
<tr>
<td>ETUC</td>
<td>European Trade Union Confederation</td>
</tr>
<tr>
<td>EU</td>
<td>The European Union</td>
</tr>
<tr>
<td>FCPC</td>
<td>Food and Consumer Products of Canada</td>
</tr>
<tr>
<td>FDA</td>
<td>Food and Drug Administration (United States)</td>
</tr>
<tr>
<td>F&amp;FP</td>
<td>Food and Food Packaging</td>
</tr>
<tr>
<td>F&amp;FPA</td>
<td>Food and Food Packaging, including Agriculture</td>
</tr>
<tr>
<td>F&amp;FPN</td>
<td>Food and Food Packaging incorporating Nanotechnologies</td>
</tr>
<tr>
<td>FICCI</td>
<td>Federation of Indian Chamber and Commerce Industry</td>
</tr>
<tr>
<td>FoE</td>
<td>Friends of the Earth</td>
</tr>
<tr>
<td>FP</td>
<td>Food Packaging</td>
</tr>
<tr>
<td>FQRNT</td>
<td>Fonds Québécois de la Recherche sur la Nature et les Technologies</td>
</tr>
<tr>
<td>FSA</td>
<td>Food Safety Authority</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>FSANZ</td>
<td>Food Standards Australia New Zealand</td>
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<td>FSCJ</td>
<td>Food Safety Commission of Japan</td>
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<tr>
<td>FSSAI</td>
<td>Food Safety and Standard Authority of India</td>
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<tr>
<td>GAO</td>
<td>United States Government Accountability Office</td>
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<tr>
<td>GM</td>
<td>Genetically Modified</td>
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<tr>
<td>GMO</td>
<td>Genetically Modified Organisms</td>
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<tr>
<td>GoC</td>
<td>Government of Canada</td>
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<tr>
<td>GoI</td>
<td>Government of India</td>
</tr>
<tr>
<td>GRAS</td>
<td>Generally Recognised As Safe</td>
</tr>
<tr>
<td>ICAR</td>
<td>Indian Council of Agricultural Research</td>
</tr>
<tr>
<td>ICMR</td>
<td>Indian Council of Medical Research</td>
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<tr>
<td>IDRC</td>
<td>International Development Research Centre</td>
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<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<tr>
<td>IFFCO</td>
<td>Indian Fertilizer Co-operative Society of India</td>
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<tr>
<td>IFOAM</td>
<td>International Federation of Organic Agriculture Movement</td>
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<tr>
<td>IISc</td>
<td>Indian Institute of Science</td>
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<tr>
<td>IIT</td>
<td>Indian Institute of Technology</td>
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<tr>
<td>IITR</td>
<td>Indian Institute of Toxicological Research</td>
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<tr>
<td>ILSI</td>
<td>International Life Sciences Institute</td>
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<tr>
<td>INR</td>
<td>Information Request Notice</td>
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<tr>
<td>IP</td>
<td>Intellectual Property</td>
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<tr>
<td>IRAP</td>
<td>Industrial Research Assistance Program</td>
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<tr>
<td>IRGC</td>
<td>The International Risk Governance Council</td>
</tr>
<tr>
<td>IRSST</td>
<td>Institut de recherche Robert-Sauvé en santé et en Sécurité du travail</td>
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<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>ISAD</td>
<td>International Science and Technology Directorate</td>
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<td>ISO</td>
<td>International Standardization Organization</td>
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<td>ISTP</td>
<td>International Science and Technology Partnership</td>
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<tr>
<td>JRC</td>
<td>Joint Research Centre</td>
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<tr>
<td>KVK</td>
<td>Krishi Vigyan Kendra</td>
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<tr>
<td>MEP</td>
<td>Member of the European Parliament</td>
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<tr>
<td>MDGs</td>
<td>Millennium Development Goals</td>
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<td>MNC</td>
<td>Multi-National Corporations</td>
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<tr>
<td>MoHFW</td>
<td>Ministry of Health and Family Welfare</td>
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<td>NAFTA</td>
<td>North American Free Trade Agreement</td>
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<tr>
<td>NAARM</td>
<td>National Academy of Agricultural Research Management</td>
</tr>
<tr>
<td>NAIP</td>
<td>National Agricultural Innovative Project</td>
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<tr>
<td>NCBS</td>
<td>National Centre for Biological Sciences</td>
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<tr>
<td>NCC</td>
<td>Nano Crystalline Cellulose</td>
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<tr>
<td>NCL</td>
<td>National Chemical Laboratory</td>
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<tr>
<td>NDRI</td>
<td>National Dairy Research Institute</td>
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<tr>
<td>NE³LS</td>
<td>Nanotechnology Ethical, Environmental, Economic, Legal and Social Issues</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental Organisation</td>
</tr>
<tr>
<td>NIA</td>
<td>Nanotechnology Industries Association</td>
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<tr>
<td>NIANP</td>
<td>National Institute of Animal Nutrition and Physiology</td>
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<td>NIMITLI</td>
<td>New Millennium Indian Technology Leadership Initiative</td>
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<td>NIN</td>
<td>National Institute of Nutrition</td>
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<td>NIOSH</td>
<td>National Institute for Occupational Safety and Health</td>
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<tr>
<td>N&amp;N</td>
<td>Nanoscience and Nanotechnology</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>NNI</td>
<td>Nanotechnology National Initiative</td>
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<tr>
<td>NPL</td>
<td>National Physical Laboratory</td>
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<tr>
<td>NRC</td>
<td>National Research Council</td>
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<tr>
<td>NRCG</td>
<td>Nanotechnology Research Coordination Group</td>
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<tr>
<td>NS</td>
<td>New Substances</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
<tr>
<td>NSERC</td>
<td>Natural Sciences and Engineering Research Council</td>
</tr>
<tr>
<td>NSN</td>
<td>New Substances Notification</td>
</tr>
<tr>
<td>NSNR</td>
<td>New Substances Notification Regulations</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>OMAFRA</td>
<td>Ontario Ministry of Agriculture Food and Rural Affairs</td>
</tr>
<tr>
<td>OMRI</td>
<td>Organic Materials Review Institute</td>
</tr>
<tr>
<td>PEN</td>
<td>Project on Emerging Technology</td>
</tr>
<tr>
<td>PGP</td>
<td>Plant Growth Promoters</td>
</tr>
<tr>
<td>PGR</td>
<td>Plant Growth Regulators</td>
</tr>
<tr>
<td>PHA</td>
<td>Pulmonary Hypertension Association of Canada</td>
</tr>
<tr>
<td>PNC</td>
<td>Pre-notification Consultation</td>
</tr>
<tr>
<td>RCC</td>
<td>Regulatory Cooperation Council</td>
</tr>
<tr>
<td>RCEP</td>
<td>Royal Commission on Environmental Pollution</td>
</tr>
<tr>
<td>RCR</td>
<td>Responsible Conduct of Research</td>
</tr>
<tr>
<td>REACH</td>
<td>Registration, Evaluation, Authorization and Restriction of Chemicals</td>
</tr>
<tr>
<td>REB</td>
<td>Research Ethics Board</td>
</tr>
<tr>
<td>ResAGorA</td>
<td>Responsible Research and Innovation in a Distributed Anticipatory Governance Frame</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>RI</td>
<td>Responsible Innovation</td>
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<tr>
<td>RRI</td>
<td>Responsible Research and Innovation</td>
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<tr>
<td>SCC</td>
<td>Standards Council of Canada</td>
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<tr>
<td>SEM</td>
<td>Scanning Electron Microscope</td>
</tr>
<tr>
<td>SERC</td>
<td>Science and Engineering Research Council</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium-sized Enterprise</td>
</tr>
<tr>
<td>SSHRC</td>
<td>Social Sciences and Humanities Research Council</td>
</tr>
<tr>
<td>S&amp;T</td>
<td>Science and Technology</td>
</tr>
<tr>
<td>TARA</td>
<td>Technology and Action for Rural Advancement</td>
</tr>
<tr>
<td>TCPS</td>
<td>Tri-Council Policy Statement</td>
</tr>
<tr>
<td>TEM</td>
<td>Transmission Electron Microscopes</td>
</tr>
<tr>
<td>TN</td>
<td>Tamil Nadu</td>
</tr>
<tr>
<td>TNAU</td>
<td>Tamil Nadu Agricultural University</td>
</tr>
<tr>
<td>TNC</td>
<td>Trans-National Corporation</td>
</tr>
<tr>
<td>U.K.</td>
<td>United Kingdom</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>U.S.</td>
<td>United States</td>
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<tr>
<td>WHO</td>
<td>World Health Organisation</td>
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<tr>
<td>WTO</td>
<td>World Trade Organization</td>
</tr>
<tr>
<td>WPMN</td>
<td>(OECD) Working Party on Manufactured Nanomaterials</td>
</tr>
</tbody>
</table>
Abstract

Submitted to The University of Manchester by Rumana Bukht for the Degree of Doctor of Philosophy, titled “Responsibility, Regulation and the Construction of Markets of Nanotechnologies in Food and Food Packaging: The Cases of Canada and India”, Mar 2016.

Scientific research, technological development, and commercialisation are processes through which new technologies continually emerge and enter markets. Nanotechnology is an example of an emergent technology (or rather a suite of technologies) which promises to open up a universe of possibilities for the development of new products and processes. Advocates of the technology argue that nanotechnology has the potential to spur economic development while at the same time offering partial solutions to many of the grand challenges of our times such as alleviating hunger, providing new energy sources, reducing climate change, curing diseases, etc. However, alongside these optimistic views, there are also fears and apprehensions concerning the safe and ethical development of nanotechnologies, including the need to address potential negative impacts on the natural environment and human health and safety.

The food and food packaging area has shown itself to be a particularly sensitive sector in this respect where the potential for nanoparticles to enter the human body has enhanced the sensitivity of the industry to public concern. The past has shown that any changes or modifications made to food have resulted in public backlash (e.g. GM foods). Due to this some parts of the food and packaging industry remain cautious about making transparent their use of nanotechnologies in their products and processes. However, simultaneously pressure is mounting from regulatory agencies, and from some activists, to pursue the safe and ‘responsible’ development of nanotechnologies (whatever that may be) as an ethical obligation.

The use of nanotechnologies in food and food packaging has become increasingly complex because of its introduction at various points in the food chain, giving rise to debates as to “who is responsible”. As a contribution to the debate on what constitutes the ‘responsible’ governance of new/emergent technologies, this thesis investigates the governance of nanotechnologies and the idea of ‘responsibility’ and ‘responsible innovation’ through the lens of perspectives of different actors within the nanotech food chain. A qualitative research methodology was used where semi-structured interviews were conducted with a heterogeneous group of actors with a particular focus on the food and food packaging sectors. Research in comparative national settings (Canada and India) was conducted on the grounds that regulation of nanotechnologies differs significantly across OECD and non-OECD countries, and where the global debate on nanotechnologies is organised and dominated by OECD countries.

Findings from this thesis showed that the set of critical elements, such as health and safety, that are put forward by such OECD countries like Canada for the ‘responsible’ development of nanotechnologies are not the same as that found in India and are seen to differ. In India, meeting the grand challenges of society such as food security, clean drinking water and alleviating poverty take precedent over other elements, where science, technology (such as nanotechnologies) and innovation are harnessed by entrepreneurs, and small and large firms to solve these national problems. However, while I began the study with the intention of comparing two national territories with different regulatory settings, the study also found a case of collaborative Canada-India transnational research network where ‘responsibility’ is influenced through certain funding criteria set by the more dominant partner, Canada. This suggests the return of public intervention by dominant OECD countries in pro-actively shaping R&D processes that are influencing the ‘responsible’ development of nano-products in such emerging markets, where there is a potential for future trade associations.
Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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Dedicated to the memories of:

**Zafar Aslam**, Uncle

(10.10.1967 – 11-06-2012)

&

**Priya Rao**, Friend

(07-10-1977 – 21-04-2013)

*Forever missed.*
Acknowledgement

The challenges of a PhD can only be known to those who have made it thus far. While I would not want to attempt another ‘thesis of acknowledgements’, it would be worthless without thanking some of my acquaintances, family and friends, who helped me climb this ladder.

First, I would like to thank the ‘anonymous’ benefactor who graciously funded three years of the programme fees, and the University of Manchester (UoM) for providing me the opportunity to fulfil another dream through this scholarship.

Second, no thesis is complete without the participation of respondents; I would therefore like to thank all those participants who very kindly gave up their time to be interviewed and contributed to the accomplishment of this thesis. Also, I am most thankful to RADMA for the grant, which enabled me to travel to Canada for fieldwork, and to the CISN funders for their support. My special thanks goes to Virginia Mann and ‘Rick’ for their help in connecting me to some of the respondents; and Karen Mann for her hospitality and extensive support during my fieldwork in Canada.

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About the Author

Rumana Bukht earned a Masters course in Corporate Communications and Reputation Management from Manchester Business School with a distinction in 2008. She also holds a Post-Graduate Diploma in Business Administration (PGDBA) and has studied an undergraduate course in science - a BSc in Chemistry, Botany and Zoology.

Rumana was the co-author of the research project “Top Performing Cluster in the UK - NanoSciences & NanoTechnologies (N&N), the case of Manchester”, for the National Research Council Canada (NRCC). She was also briefly involved in the European Commission’s FP7 Nanoplat project, where the University of Manchester was responsible for the package of work scoping trans-Europe issues on N&N in food and packaging.

Rumana has over 15 years of experience in international technology Marketing and has a track record of streamlining marketing/communications strategies for large multinationals, and initiating and establishing Corporate Social Responsibility (CSR) departments and strategies. The PhD programme of research and study is in continuum of her professional practice in the field of CSR, and her background and research interest in science and technology.

Rumana has held various managerial positions with leading IT companies. Prior to joining the PhD programme, she worked as a Senior Marketing Consultant at an inter-governmental Commonwealth Organisation in London that was involved in bridging a gap in Information Communication and Technology (ICT)/Information Technology (IT) between developed and developing countries.

Rumana was awarded the University of Manchester’s Research Impact Scholarship under the Alumni Scholarship scheme for the three years of the PhD programme at the Manchester Institute of Innovation Research (MIoIR), Manchester Business School.
Presentations at conferences

Part of this thesis has been presented at conferences/seminar or were accepted abstracts at conferences:

Conference presentations

- **Four Avenues of Regulating Nanotechnologies ‘Responsibly’ in Canada**
  The ‘Responsible’ Development of Nanotechnology: Challenges and Perspectives, Ne3LS Network International Conference 2012, November 1-2, 2012, Montreal, Canada

- **Intervention of the State on ‘responsible’ development of nanotechnologies in Canada**
  S.Net (Society for the Study of Nanoscience and Emerging Technologies) 2012, October 22-25, 2012, Twente, The Netherlands

Accepted Abstracts

- **Common and Disparate Notions of ‘Nano-responsibility’: A Cross-national Comparative Perspective of Canada and India**
  S.Net (Society for the Study of Nanoscience and Emerging Technologies) 2013, October 27-29, 2013, Boston, U.S.A.

- **Role of NGOs in facilitating ‘responsible’ development of nanotechnologies in Canada and India**
  The Democratizing Technologies: Assessing the Roles of NGOs in Shaping Technological Futures Conference, November 13-15, 2014, California, U.S.A.
Seminar

- Governance of Nanotechnologies through Varied Domains of ‘Responsibility’: A Comparative Perspective of Canada and India

1 April 2015, Keele University, U.K
CHAPTER 1

INTRODUCTION

1.1. Background

1.1.1 Innovations in science and technology

We live in an age of high technology that bring with it great opportunities as well as challenges that influence our daily lives. New innovations continually emerge and enter markets through processes of scientific research, technological development, and commercialisation. Much importance is given to research and innovation in science and technology (S&T) as it is seen to provide solutions for some of the grand challenges of life in the 21st century, such as healthcare, climate change, poverty, ageing population, food security, among others.

Innovation has been defined as new (technological) breakthroughs that are applied to new processes, products and services, which can bring value to society (Nelson and Winter 1977; Voeten et al. 2009). It has become the foundation of various national government strategies for economic growth and competitiveness. The process and impacts of innovation over the past century has been visible in various public, business and policy decisions. While governments are constantly looking for investments and growth in their economy through innovation, firms want to capture a bigger share in the competitive domestic and international markets through innovation. Over the past years, technological innovation has been slowly dominated by commercial imperatives, which is seen to bring benefits to society quickly. New and emerging technologies are seen as a way of serving most pressing human and societal needs (Roco 2007; Roco 2006; National Research Council 2006).

However, not everyone sees developments in S&T to necessarily bring benefits to society (Callon et al. 2009). While many see a potential in commercialisation and competitiveness, others believe that there is a hype and over-enthusiasm about technological innovation. Moreover, technological innovations are defined by their uncertainty and are unpredictable (Pavie et al. 2014; Stilgoe 2014). They bring along with them new and emerging risks and moral and ethical dilemmas. Thus, the potential “gain in power from techno-economic
‘progress’ is being increasingly over-shadowed by the production of risks” (Beck 1992), which is inherent in all technological innovations.

Additionally, the uncertainty surrounding the future unintended (negative) impacts of innovation has been contentious, especially where it has led to various forms of incremental and radical innovations and is disruptive to society, cultures and the environment (Macnaghten and Chilvers 2014). Thus, while innovation can serve people’s needs, at the same time it may not be “inherently good” (von Schomberg 2014).

Furthermore, the evolution of technological innovation, while bringing benefits can also bring risks (Hellstrom 2003) which are unknown. History has shown that the ambiguity of innovation can lead to different outcomes and perceptions that are diverse and polemic. This is especially evident in the case of genetically modified organisms (GMO)¹ where the resulting controversies and ethical issues have resonated in societal backlash, generating economical counter-effects, which were not predictable. Therefore, there is no guarantee that research and innovation can bring guaranteed success to solving problems, such as the grand challenges of society (Stilgoe 2014).

Thus, S&T, which one would imagine would solve all our socio-economic needs, does not necessarily, bring in greater certainty; instead it has brought more uncertainty (Callon et al. 2009b, p.18). Because the uncertainties deal with health and environment, these have led to a rise in socio-technical controversy which brings to the fore a need to deal with the social acceptability of technologies (Callon et al. 2009, p.13). The uncertainties and potential impacts surrounding innovation also increases the complexity of governance of innovation processes, which cannot be resolved through a top-down governance approach (Gianni et al. 2014). While no technological innovation is without risk (Hellstrom 2003, p.379), in order to gain full benefit from S&T it is important that concerns of environment, health and safety (EHS) and ethical, legal and social issues (ELSI) are researched (Satterfield et al. 2009) and its impacts on the health and environment fully assessed (European Commission 2015; Roman 2015).

¹ A genetically modified organism (GMO) is one whose genetic make-up (or DNA) has been changed or genetically modified by the technological process of genetic engineering which involves “inserting genes or other sequences of genetic code from one class of organisms into another.” (Thompson 2007)
1.1.2 Emerging nanotechnologies - benefits and risks

Emerging technologies can be defined as science-based, novelty technologies with potentially broad impacts that have shown high growths recently (Cozzens et al. 2010). Nanotechnology is an example of one such emergent technology (or rather a suite of technologies) which promises to open up a universe of possibilities for the development of new products and processes. The National Nanotechnology Initiative (NNI) of the United States of America (U.S.) has defined nanotechnology as “the understanding and control of matter at dimensions between approximately 1 and 100 nanometers (nm), where unique phenomena enable novel applications” (NNI 2014). Advocates of the technology argue that nanotechnology has the potential to spur economic development while at the same time offering partial solutions to many of the grand challenges of our times such as alleviating hunger, providing new energy sources, dealing with climate change, curing diseases, among others.

The transformational potential of nanotechnologies has received much interest among the scientific community, organisations and governments around the world. Due to globalisation there is a potential for a growth in markets for nanotechnologies not only in developed countries, but in developing countries and emerging markets. Several developing nations have harnessed nanotechnology initiatives where nanotechnologies are expected to provide economic and industrial benefits as well as address some of the Millennium Development Goals (MDGs) set by the United Nations (UN)² (Salamanca-Buentello et al. 2005). Proponents of nanotechnologies expect that the technology will offer solutions to some of the grand challenges, such as food security and water purification that currently exist in developing countries (Salamanca-Buentello et al. 2005) and emerging economies like India and China, and close existing gaps between the rich and poor nations (NIA 2013).

However, alongside these optimistic views, there are also fears and apprehensions concerning the potential negative impacts of nanotechnologies on human health and safety and the natural environment. Many nanomaterials have unusual physio-chemical properties that categorize them as potentially hazardous over conventional chemicals (Nel et al. 2006; Oberdörster et al.

² In order to promote a safer and more equitable world and end extreme poverty, in September 2000, leaders of 189 countries came together at the UN in New York to endorse the Millennium Declaration, which involved achieving eight goals by 2015 (United Nations 2000). See also http://www.un.org/millenniumgoals/
2005; Maynard 2007). However, very little is known about the potential risks of nanomaterials to human health, and these risks are only likely to emerge on a case-by-case basis (Wiesner et al. 2006). How some nanomaterials react after being ingested in the body or inhaled, and the risks associated with the technology due to their small size, are unknown. Hence, a case-by-case assessment is necessary (Kobe 2012).

The uncertainties of potential hazards of nanotechnologies have led various scientists to carry out toxicity studies to ascertain the probable risks of nanomaterials. However, while various studies have been conducted on different nanomaterials to ascertain their risks (Hoet et al. 2004), these have been largely inconclusive and the actual health and environment risks, including the deaths of humans from nano-risks (Song et al. 2009; Song et al. 2011) remain contested (Maynard 2009). Moreover, many of these studies have not followed accepted and universally recognised protocols, which gives rise to further questions about the credibility of these tests (Reich 2011). Also, the absence of a reliable definition as to what constitutes the “nanoscale” makes it difficult to establish what types of nanomaterials are used, especially in the food sector, and whether these are covered under the existing regulations. Thus, there is concern that existing risk assessment and regulatory frameworks are not sufficient to address nanotechnology risks as they are designed for conventional chemicals (Renn and Roco 2006, p.29). However, in a recent report by the European Commission (EC) (European Commission 2015), it was pointed out that the hype of nano-innovation has stimulated unreasonable fears of its safety, which, supplemented by early inadequate toxicological studies, have provided policy-makers with poor advice and made them unreasonably cautious. The report goes on to point out (with examples of recent developments) that in actuality extensive research now shows that most nanomaterials are no more toxic than its bulk forms, and those that are acutely toxic are easily identifiable. However, the report also emphasises the need to have a clear understanding of the potential hazards that may occur due to toxic nanoparticles and for scientists to “exercise good judgement”.

1.1.3 Applications of nanotechnologies in food and food packaging

The food and food packaging (F&FP) area has shown itself to be a particularly sensitive sector in terms of risks, where the potential for nanoparticles to enter the human body has enhanced the sensitivity of the industry to public concern. In recent years there has been an increased use
of nanomaterials in F&FP and agriculture (Chaudhry, Scotter, et al. 2008) and a variety of products and applications are being developed and commercialized. In a report in August 2006, UK-based research firm, Cientifica, estimated nanotechnologies in the food industry to be valued at US$410m, and is expected to grow to US$20.4 billion by 2020 (Helmut Keiser 2003).

Applications of nanotechnology in F&FP sectors range from improved food safety and enhanced packaging to improved processing and nutrition (Neethirajan and Jayas 2011). This includes nano-films for food packaging and contact materials to extend shelf-life, preserve quality and decrease cooling requirements (Scott and Chen 2012). In food, nanotechnology is used to improve taste, enhance the bioavailability of ingredients/nutrients (Miller 2010); reduce fats, sugar and salt (and therefore develop foods with lower calories), while retaining its flavor, color and texture (Meetoo 2011; Roco et al. 2010; Tachikawa 2012); identify and detect foodborne pathogens, toxins and bacteria or spoilage, remove pathogens and undesirable chemicals and slow down microbial activity (Chaudhry and Castle 2011). In agriculture, nanotechnology is being applied to promote sustainable agriculture, improve crop production, increase yields through smart fertilizers and potentially produce better quality foods (Gruère et al. 2011; Larkins et al. 2008). Applications in this sector include uptake of nutrients using nanosensors, minimization of nutrient losses through precise and controlled release of fertilizers and pesticides using nano-fertilizers and nano-pesticides, and smart delivery systems using nano-herbicides and nanosensors to measure soil quality (Srilatha 2011; Sharon et al. 2010; Naderi and Danesh-Shahraki 2013; Gogos et al. 2012; Chinnamuthu and Boopathi 2009). Some research has also focused around water safety using nanosilver and nanoclay to improve water filtration (Gruère et al. 2011; Chinnamuthu and Boopathi 2009).

The rapid emergence of nanotechnologies in consumer products, including those in F&FP, has given rise to a number of societal and ethical issues, especially in developed and OECD (The Organisation for Economic Co-operation and Development) economies (Gruère 2012). Research shows that nano-based products are being developed and placed in the market without assessing their potential impacts on human health and environment (ETUC 2008). In 2008, the European Trade Union Confederation (ETUC) demanded a full compliance with the European legislation REACH’S (Registration, Evaluation, Authorization and Restriction of Chemicals) “no data, no market” policy and recommended that marketing should not be permitted (ETUC 2008; ETUC 2010).
In 2009, the British House of Lords Science and Technology Committee called for a formal investigation into the safety of usage of nanotechnologies in the F&FP sector and appointed a subcommittee to examine the issues. The subsequent evaluation report “Nanotechnologies and Food” (House of Lords 2010b), which was published in December 2009, focused on safety of nanomaterials in environmentally sustainable food products, “additives and supplements; food contact packaging; food manufacturing processes, animal feed, pesticides and fertilizers” and other products such as food containers and cooking appliances.

Over the years, various scientists have also cautioned use of nanoparticles (e.g. titanium dioxide (TiO$_2$) and silver nanoparticles (AgNPs) in several F&FP and personal products, and its disposal into the ecosystem (Weir et al. 2012; Poland et al. 2008; Song et al. 2011).

Several civil society organisations (CSOs)$^3$ have also published elaborate reports highlighting the possible risks of nanotechnologies in F&FP (Illuminato 2014; Galland and Passoff 2011; Behar et al. 2013), and calling for international moratorium until adequate regulations on nanomaterials are put in place (ETC Group 2003b).

1.1.4 Governance of nanotechnologies

In the absence of sufficient data with regards to the behaviour of nanomaterials and the uncertainty surrounding nanotechnology, the governance of nanotechnologies, including the EHS and ELSI aspects of nanomaterials, is being given much attention by various researchers and policy-makers (Kearnes and Rip 2009; Savolainen et al. 2010) and has progressed considerably over the past years across nations (Roco et al. 2011).

Various countries have established programmes to address the challenges of risk governance of nanotechnologies (Pelley and Saner 2009; House of Lords 2010a). Some countries (such as the U.S.) have also released guidance documents for industry and/or procedures to follow for nano-based food products based on existing regulations (FDA 2014). However, most countries are still lingering on whether they should bring out new regulations for nano-enabled F&FP products, and if so, how (Gruère 2012, p.195). Where there are known risks, regulation can be

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$^3$ The term is broad and often includes non-governmental organisations (NGOs), charities/trusts, foundations, advocacy groups and non-state associations (Hutter and Mahony 2004)
implemented; but in the case of scientific uncertainty, regulation can be challenging (Berube 2012). This leaves nano-innovators with further uncertainties as to when the regulation of nanotechnologies will come in place, or what form of frameworks will be put in place (Silva and Robinson 2012).

With such ambiguities surrounding nanomaterials, and growing number of products in the market, including F&FP, there have been repeated calls for the precautionary principal approach (ETUC 2008; Gee 2009; WHO 2013). Various forms of soft and hard regulations have also been introduced, including self-regulation, codes of conduct, standards, voluntary/mandatory disclosures and in some cases altogether a ban on the use of nanomaterials in food (Gruère 2012; Grobe et al. 2008; Roco et al. 2011). However, in the U.S. and Europe, such efforts through voluntary codes of conduct and risk management systems by non-governmental organisations – such as TÜV SÜD Industrie Service GmbH (CENARIO® certification), the Swiss Retailer Association - IG DHS (Code of Conduct) and DuPont and the Environment Defense Fund (EDF) (The Nano Risk Framework) - have had limited success (Senjen 2009; Dorbeck-jung 2011; Roco et al. 2011).

The globalization of food chains has further contributed to increased challenges of governance of F&FP products. The huge opportunities of new markets and patents are creating a confusion around R&D of nanofoods as there is no clarity in research in this area (Bakker et al 2014). Nanotechnologies in food pose challenges to developing regulation as current risk-based approaches do not adequately assess the potential risks of nanomaterials. The food industry is thus fearful of disclosing their activities (Chaudhry et al. 2008, p.243). Due to the fear of public backlash some parts of the F&FP industry remain cautious about making transparent their use of nanotechnologies in products and processes. However, simultaneously pressure is mounting from regulatory agencies, consumer representative groups and from some industry quarters, to pursue the safe and ‘responsible’ development of nanotechnologies (whatever that may be) as an ethical obligation.

While many OECD countries are undertaking research and development (R&D) in F&FP, the reported presence of commercialized nano-enabled products varies. Various products are known to be developed in the areas of F&FP, including supplements, anti-bacterial food and beverage containers by small and large companies (Robinson and Morrison 2010). There have
also been reports of products coming out of countries in the EU, Australia, Canada, Israel, South Korea, Brazil, China, Germany, Japan, France and the United States (Gruère 2012; Purushotham 2012; House of Lords 2010a).

With products flooding markets, regulation and governance of nanotechnologies are getting to be more and more complex. The governance of nanotechnologies is essential for social and economic development, global collaborations and protection of public health and society (Roco et al. 2011, p.3557). However, “good governance” of nanotechnologies should “enable” and not constrain nanotechnology development (Kearnes and Rip 2009; Roco and Renn 2006).

Under such conditions, and in an uncertain regulatory environment, new notions of ‘responsibility’ through the concepts of ‘responsible innovation’ (RI) and ‘research and responsible innovation’ (RRI) are increasingly being included in important policy narratives. These discussions on the ‘responsible’ development of nanotechnologies’ (whatever that may be) are gaining focus across nations and has opened up new debates as to who is responsible for the governance of nanotechnologies? Moreover, the use of nanotechnologies in the F&FP sector has become increasingly complex because of its introduction at various points in the food chain. Hence, the debate as to ‘who is responsible’ along different points - from the sourcing of raw materials, to multiple stages of processing and manufacture; to retailing to consumers – has taken centre stage.

1.2. Motivation and justification for research

As pointed out in the above section, various national and international debates on the benefits and risks of nanotechnologies are characterised by a high degree of uncertainty. Such risks have highlighted the inadequacies in regulation and responsibilities. Furthermore, contemporary innovations include the interactions of many actors which complicates issues of ‘responsibility’ as to ‘who is responsible’ (Bakker et al 2014, p.296) and who do the actors consider is responsible for governing the use of nanotechnologies.

Various debates have been growing over the issues of nanotechnologies, such as: Are the current legislations adequate? Should there be new regulations (Senjen 2009) and can we regulate nanotechnologies (Lobring 2006) in the absence of sufficient data? Most importantly,
who is ‘responsible’ for the governance of nanotechnologies and who do the actors acknowledge is ‘responsible’ to ensure safety of products in the market?

Although there has been a growing literature and journals on the ethical issues of nanotechnologies (Kjølberg and Wickson 2007; Viseu and Maguire 2012; Patra et al. 2009; Sweeney et al. 2003) and emergence of the concept of responsible innovation (Pandza and Ellwood 2013; Pavie et al. 2014; von Schomberg 2013), there are few empirical studies that investigate perceptions of ‘responsibility’/RI among various actors, specifically in the F&FP sectors. As an exception a study by Bakker et al (de Bakker et al. 2014) provides perceptions of actors in the nanofood industry in the Netherlands and a government survey conducted by the Toray Research Center in Japan looked at manufacturers’ perceptions of nanotechnology use in the F&FP and food equipment industries and co-operative associations (FSCJ 2010). However, both these studies focused on actors in an OECD economy. While some studies have focused on the perceptions of scientists in emerging nations like India (Patra et al. 2010; Sahoo 2013), these do not focus on F&FP and have limited variation of actors in their study. The Nanoplat FP7 Science in Society project involved a deliberative process involving perceptions of a range of actors from within Europe using online chat focused on nano-based consumer goods (CORDIS 2010).

As noted most of these available studies on perceptions of actors are almost exclusively considered from the perspective of developed/OECD nations, have limited variation of actors in their study, and do not specifically investigate the notion of ‘responsibility’, creating a huge gap in existing literature. Furthermore, while there has been a sharp increase in literature examining the ‘responsible’ development of nanotechnologies and its socio-economic impacts in developed countries (Seear et al. 2009), India-specific literature on the ‘responsible’ development of nanotechnologies is relatively embryonic with only a few emerging in recent years as compared to those produced in the West.

Furthermore, while there are various comparative studies on regulations of nanotechnologies, comparative perspectives across perceptions of ‘responsibility’ are virtually entirely missing from the literature. A comparative study between Europe, China and India examines the ethics debates on nanotechnologies (Fautz et al. 2014) but does not provide reflections on perspectives of actors. A comparative study by OECD on the ‘responsible’ development of
nanotechnology in twenty five countries, including emerging economies like South Africa and China (OECD WPN 2013), provides only a snapshot of research programmes, excludes India, an important emerging market and does not focus on F&FP.

This thesis attempts to shift the geographical focus and investigates the notions of ‘responsibility’ in a developing/transitioning country – India – therefore providing an understanding of responsible innovation (RI) from the perspective of an emerging/developing country, while also investigating the notions of responsibility in a developed country - Canada. By contrasting the notions of ‘responsibility’ pertaining to nanotechnologies in developed and developing economies, this thesis therefore provides a benchmark for contrasting notions of ‘responsibility’ in nanotechnology between an OECD and a non-OECD economy, currently absent in literature.

Thus, despite the growing questions on who should be responsible for the ‘responsible’ governance of nanotechnologies, the current literature does not provide empirical studies that specifically focus on the perceptions of ‘responsibility’ of actors in F&FP on a comparative context between developed and developing/transitioning countries. This thesis seeks to help fill this gap and contribute to the existing literature in that area.

Based on the observations and arguments developed above, this study investigated the ‘responsible’ governance of nanotechnologies in the F&FP industries in two extremely different and oppositely diverse settings – India, a developing/emerging country with limited or low regulatory standards; and Canada – a developed country considered to have very high regulatory standards. As there is limited information available on the global governance of nanotechnologies in the F&FP sectors, this research will help to throw some light on the notions of ‘responsibility’/RI among actors within the F&FP industry in Canada and India. Both these countries have over the last decade, been actively involved in nanotechnology R&D and this study provides an understanding on the ‘responsible’ development of nanotechnologies through the lens of actors within their individual national settings. This study concentrates on wider governance approaches rather than regulatory issues. The (potential) regulation of novel nanotechnologies is increasingly perceived as one element of the broader landscape of governance (Kearnes and Rip 2009, p.2). Therefore, the focus of this study is governance of nanotechnologies where regulation is used as one dimension to investigate ‘responsibility’.
The F&FP sectors were selected because it is an area that is sensitive to issues of safety and consumer acceptability as has been seen in earlier debates for GM foods; and also due to the potential entry of nanotechnology at different points of the food chain.

While my initial proposed research was to investigate nanotechnologies and corporate responsibility in the F&FP sector, due to the industry’s secrecy, it became clear at a very early stage of this study that the governance of nanotechnologies was far more complex that involved the participation of a heterogeneous group of actors, rather than a single entity. This study therefore takes into perspective the notions of a varied selection of actors with varied roles and responsibilities; and from various public-private-non-governmental institutions.

The selection of the two cases, Canada and India, was the result of two stories that appeared in the media. In 2009, with growing dilemmas of regulation and ‘responsibility’, extensive media coverage announced that Canada was to become the first country in the world to call for mandatory reporting of use of nanomaterials by companies (The Canadian Press 2009). As an OECD country Canada endeavours to keep ahead of innovation and technology and the announcement created much interest and attention around the world. A year later another media article grabbed my attention, this time in a non-OECD, emerging country, India. The article raised questions about the risks of nanotechnology in products in the Indian market. The two countries, though distinctly different in their social and regulatory approach, seemed to demonstrate a similar stance on nanotechnologies, which peaked my interest and led me to this PhD programme.

While the main focus of my research project is Canada, my rationale to include India, an emerging BRICS (Brazil, the Russian Federation, India, China and South Africa) economy, as a second order case, is to contest the case of a highly regulated region. A further explanation is provided below.

**Why India**

- **BRICS country:** The increasing ease of communication between nations and globalisation has created a “supply and demand” for information on “foreign countries” (Rose and Mackenzie 1991). India is an OECD-interest country and a BRICS economy. India is involved in key OECD initiatives and is on various OECD committees. With
the growth of its stature in the global economy, India attracts much interest from the international community and is being reviewed by OECD to be inducted as a full member OECD country in the near future (Deccan Herald 2011). Moreover, India is a country that has benefited from globalisation by leveraging the growing “internationalization of innovation” and is envisaged in future to emerge as a “technological superpower” (Segal 2008), which makes many developed countries interested in the future trajectory of innovations in this country.

- **Competing within the global market:** India joined the nanotechnology bandwagon very late (TERI 2009b; Sharon 2013; Ramani et al. 2010). However, in order to compete in the global market and not be left out, India, within a short span of ten years has been playing ‘catch-up’ through various R&D programmes and initiatives of nanotechnologies by leveraging on its resources and skills (Sastry et al. 2011; Ramani et al. 2010), making it one of the emerging major players in the global market for nanotechnologies.

- **Large market:** India is a huge market and many large corporations have vested interest in the country. Various large multi-national corporations (MNCs) have set up shop in India and some have invested in R&D of nanotechnologies as they see India as a potential for a big/profitable market for commercialisation of nano-based products. India is thus expected to play a crucial role in nanotechnology R&D and commercialisation.

- **Limited regulatory standards:** India is considered as an example of a country with potentially limited regulatory standards. As a growing economy and a potential for a huge market for nano-products, there is much interest from international regulatory institutions on the route being taken by India in the safe and ‘responsible’ development of nanotechnologies. Though India joined the nanotechnology bandwagon very late (TERI 2009b; Sharon 2013; Ramani et al. 2010), over the last decade, India is ‘catching-up’ in the development of R&D of nanotechnologies (Sastry et al. 2011; Ramani et al. 2010) and thus is expected to play a crucial role in nanotechnology R&D and commercialisation. With a potential for a huge market for nano-products in India, the governance stance taken by India makes an interesting case to study. Moreover,
India became the first country in the world to mandate a minimum corporate spend of 2% of their profits as a CSR initiative (GoI 2014), which makes it a good case to study for its perspectives on ‘responsibility’.

**Why Canada**

- *OECD country:* As one of the founders of the OECD, Canada has, over the past 50 years, contributed as well as benefitted as a member of OECD.

- *Competing within the global market:* As a developed nation Canada keeps ahead of global competition through innovation fields such as nanotechnologies and, like India, has a strong position in terms of exporting food commodities.

- *Large market share:* Canada has a large market share in global investment in nanotechnologies. Canada also has a large market share in food commodities and has made various investments in new technologies, especially in agriculture. This brings Canada to the forefront for the development of nano-products, with a large number of institutions already undertaking R&D in Canada through the support of the central and provincial governments. Canada has many firsts to its credit in terms of nanotechnologies, including the first country to approve use of nanocellulose and establish a definition for nanotechnologies. In 2009, Canada came into the media limelight when it was announced that the country was bringing mandatory reporting of use of nanomaterials by companies, making it the first country in the world to do so (The Canadian Press 2009).

- *High regulatory standards:* As an OECD country Canada is seen to have very high standards of regulation with stringent laws and legislations. Canada is also a nation with high expectations from corporations on responsible behaviour and is thus seen to have a high credibility record in terms of social responsibility. As recent as November 2014, the Government of Canada (GoC) enhanced its Corporate Social Responsibility (CSR) strategy (GoC 2014), initially launched in 2009, through consultations with local stakeholders as well as those in developing countries. This demonstrates the nation’s
high standards of values, and expectations from companies operating abroad with the highest ethical principles, making it an important case for the study of ‘responsibility’.

1.3. Research objective

My research objective was to investigate the notions of ‘responsibility’ for the safe and ‘responsible’ development of nanotechnologies in F&FP (including agriculture) through the lens of perspectives of different actors within the nanotech food chain in comparative national regulatory settings - a ‘less regulated’ BRICS nation (India) and a ‘highly regulated’ OECD nation (Canada).

These notions are examined through the following research questions.

1.4. Research questions

The main research questions that were answered in this study include:

- How do notions of ‘responsibility’ and regulation affect different geographies and markets for nanotechnology?

Sub-questions

- How is the ‘responsible’ development of nanotechnologies (for food and food packaging sectors) influenced by national regulation and governance regimes?
- How is the ‘responsible’ development of nanotechnologies (for food and food packaging sectors) shaped by the normative framing of technology (and their interpretation of what it is to be ‘responsible’) in each region?

In order to investigate the above research questions, and to understand the ways nanotechnologies emerge under different institutional frameworks and what it means to act ‘responsibly’ across two disparate regulatory settings (Canada and India), I developed a three-dimensional analytical framework (see Figure 9 in Chapter 3) combining responsibility, 

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4 Formal laws, regulations, and procedures, and informal conventions, customs, and norms
regulation, and region/spatiality (developed-OECD/emerging - non-OECD). These three components outline the basic elements of RI for emerging technologies and are analysed separately and also in their inter-relations/interactions in order to understand how notions of ‘responsibility’/RI and governance play out in different national settings.

Using the conceptual framework as a base, and in order to arrive at the answers to my research questions, I investigated the following questions: (i) what are the existing regulatory governance structures within Canada and India; (ii) what does the notion of ‘responsibility’ (and/or responsible innovation) pertaining to nanotechnologies mean to different actors in F&FP sectors and how is it ‘practiced’ in Canada and India; (iii) how (and if) these notions of ‘responsibility’ and responsible innovation are influencing the governance of nanotechnologies in the F&FP industries in the two regions; and therefore (iv) how (and if) markets for nanotechnologies in F&FP are being shaped through these notions of ‘responsibility’ and governance regimes, locally and internationally.

1.5. Research methodology

Based on the epistemological assumptions of my research question, which seeks to extract information on the notions of ‘responsibility’ through the lens of actors within the nanotech food chain in Canada and India, I chose to use a qualitative methodology for my research. Specifically, in-depth (mostly elite) interviews were carried out across a heterogeneous group of actors in Canada and India. A comparative case study analysis was also carried out.

This study provides information on current national regulatory and research governance programmes related to the ‘responsible’ development of nanotechnology in Canada and India through perceptions of ‘responsibility’. It must be stressed at the outset that what is not being attempted here is a definition of ‘responsibility’ or RI pertaining to emerging technologies, and nanotechnologies per se.

For the purpose of this study the ‘responsible’ development of nanotechnology is described “as actions to stimulate the growth of nanotechnology applications in diverse sectors of the economy, while addressing the potential risks and the ethical and social challenges the technology might raise.” (OECD WPN 2013).
1.6. Research findings

There were three main findings: (i) The notions of ‘responsibility’ in Canada and India are seen to differ where R&D and commercialisation of nanotechnologies in India are carried out under notions of ‘responsibility’ to serve the poor; (ii) Public intervention is pro-actively shaping R&D processes of nanotechnologies in a ‘responsible’ way in India through funding criteria set by dominant OECD partners; and (iii) Symmetric notions of responsibilities are being distributed in an asymmetric landscape with differences in regulatory requirements through Canada-India transnational research networks.

The findings suggest that the set of critical elements, such as health and safety, that were put forward by Canada, a highly regulated OECD country, for the R&D of nanotechnologies are not the same as those found in India and are seen to differ. I argue that in India, meeting the grand challenges of society such as creating food security, providing clean drinking water and alleviating poverty by increasing income of poor farmers are given greater priority over other elements. This notion of ‘responsibility’, whereby use of nanotechnologies to ‘serve poor people’ and provide benefits to mankind in India, is harnessed by entrepreneurs, scientists at public institutes and small and large firms to solve national dilemmas that have long existed. Conversely, in Canada, risk aversion is a greater priority, where emphasis is on scientific-based evidence research and stringent laws to avoid risks. Thus, ideas of ‘responsible innovation’ are seen to differ in these two diverse regulatory settings. Under such differences in the framings of technology, the trajectory of nanotechnology research, development and commercialization of nano-based F&FP products in India is based entirely on actors’ notions of ‘responsibility’ for societal development, unlike their developed counterparts.

While I began this study with the intention of comparing two national territories with different regulatory settings – Canada, potentially a highly regulated nation with India, potentially a nation with low regulation or with limited regulation - this study uncovered cases of collaborative Canada-India transnational research networks with distributed responsibilities across the two regions, where the criteria for R&D of nanotechnologies are influenced by the dominant OECD partner that set out certain conditions that govern how R&D of nanotechnologies is carried out in India. This finding suggests the return of public intervention in pro-actively shaping R&D processes of nanotechnologies and therefore influencing the R&D
of nano-products in a ‘responsible’ way in such emerging markets, where there is a potential for future trade associations. This result points to symmetric notions of responsibilities in an asymmetric landscape with differences in regulatory requirements.

1.7. Structure of thesis

This thesis is structured as follows.

The thesis is divided into eight chapters, as represented in Figure 1.

Following an introduction of this study in Chapter 1, in Chapter 2, I provide a critical literature review, which offers a description of the developments and discussions on nanotechnologies, with a focus on the F&FP sectors. The chapter begins by defining nanotechnology and goes on to review the recent growth and use of nanotechnologies, including in F&FP areas in developed and developing countries. The chapter concludes with a brief profile of the technology use in Canada and India, while focusing on the existing regulatory settings within these regions.

Following the section on literature review, in Chapter 3, I go on to develop a conceptual framework, and provide the research questions, which will inform my empirical studies. I provide the conceptual framework for analysing governance of nanotechnologies in developed and developing countries by focusing on related literature in responsibility and regulation.

In Chapter 4, I discuss the research methodology and outline the research design.

Chapters 5 and 6, the empirical chapters, incorporates the findings and analysis of the two cases of my study. Here, the main findings with regards to regulation, notions of ‘responsibility’ and R&D of nanotechnologies are discussed in the two settings of my cases, Canada (Chapter 5) and India (Chapter 6).

In the penultimate section of this thesis, Chapter 7, I will provide a comparative case study analysis of my two cases, Canada and India, by focusing on my key themes of ‘responsibility’, regulation and markets of nanotechnologies. While carrying out a comparative analysis I will reflect and discuss outcomes against existing theory and literature.
The conclusion chapter, Chapter 8, is divided into four sections. After a brief introduction in section 8.1, in sections 8.2 and 8.3, I revisit my questions and discuss the notions of ‘responsibility’ as practiced in the two cases of my study, Canada and India. I will discuss the governance of nanotechnologies through regulation and notions of ‘responsibility’/responsible innovation, which serves as background questions for this thesis, and present my final results. Section 8.3.1 provides my contribution to knowledge and literature through this study. Section 8.3.2 identifies and outlines areas for future research on governance of nanotechnologies. Section 8.2.3 discusses the limitations of this research. The final section of the thesis, Section 8.3.4 of Chapter 8, culminates with preliminary recommendations, which include improving mechanisms in facilitating bi-directional exchange, conversations and discursions between developed and developing countries on policy and safety tests of nanotechnologies. (See Figure 1 for diagrammatic representation of thesis chapters).
Figure 1: Diagrammatic representation of thesis structure
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

2.1.1 Aim of this chapter

The aim of this chapter is to provide a background on the existing theoretical literature and identify the gaps which forms a basis for this study. In doing so, this chapter examines the emergent concept of RI by exploring the existing literature on regulations, risks and governance of nanotechnologies, while focusing on F&FP. The review of this literature focuses on the theories, key issues, findings by other researchers, and the main points of view and controversies that surround issues being investigated. It also focuses on the strengths and weaknesses of previous studies and thus provides a critical evaluation of these views. From this review, this chapter identifies existing gaps in the literature, which have led to the research questions of this thesis. It identifies gaps in the notions of ‘responsibility’ where issues of nanotechnologies are unaddressed. It then concludes with how my research aims to fill the existing gaps in the area of 'responsibility'/RI pertaining to nanotechnologies.

2.1.2 Chapter sections

This chapter consists of five sections. The first section, section 2.1, provides an introduction to the chapter, including the main aims and objectives of the literature review chapter. Section 2.2 offers an overview of nanotechnologies, comprising a brief history and definition of nanotechnologies, its application for socio-economic development in developed as well as developing countries, and potential use in F&FP. The section reports on the risks, uncertainties and gaps in knowledge of nanomaterials and challenges in governing the technology. This is achieved by focusing on existing forms of regulation through various voluntary and non-voluntary approaches.

The third and fourth sections, section 2.3 and section 2.4, outlines the literature on the existing regulatory frameworks and governance of nanotechnologies within the food and packaging
industries in Canada and India, respectively. The purpose of these sections is to define the roles and responsibilities of various institutions in governing nanotechnologies in F&FP as pertains to these two economies.

The gaps in literature are identified in section 2.4. Finally, section 2.5 provides the concluding remarks for this chapter.

2.2 Nanoscience and nanotechnology

2.2.1 What is nanotechnology?

The prefix ‘nano’ comes from a Greek word that means dwarf (Whatmore 2006). In a commonly used definition, nanotechnology has been defined as involving the “manipulation of matter at a very small scale – generally between 1 and 100 nanometers” (Cushen et al. 2012), where “unique phenomena enable novel applications” (NNI 2013). One nanometer is $10^{-9}$ meters or a billionth of a meter or 3.28 billionths of a foot, nearly 80,000 times thinner than hair (Sahoo 2013; The Royal Society & Royal Academy of Engineering 2004; Renn and Roco 2006; NNI 2014).

Nanomaterials may be natural (wildfire smoke/volcanic ash), incidental (pasteurisation of milk/flour milling) or engineered (intentionally manufactured such as nanocarbon tubes, nanosilver). The European Commission defines a nanomaterial as:

"A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm." (European Commission 2011)

European Commission Recommendation (2011/696/EU)

The idea and concepts of nanoscience and nanotechnology (N&N) was first put forward by Richard Feynman as early as December 1959, when through his talk, titled “There’s Plenty of Room at the Bottom” at the California Institute of Technology, he described a process by which scientists would be able to control and manipulate atoms and molecules at a very small scale.
(nanoscale). It was, however, a Japanese scientist named Taniguchi who, in 1974, first introduced the term ‘nanotechnology’ at the International Conference on Production Engineering in Tokyo, while referring to the ability of engineering at the nanometer level (Taniguchi 1974). However, it was not until 1981, when the Scanning Tunnelling Microscope (STM) was invented at IBM, by Gerd Binnig and Heinrich Rohrer, that actual progress in nanotechnologies began (Baird and Shew 2004). The advent of the Atomic Force Microscopy (AFM) in 1986 (Binnig and Rohrer 1983) further led to the possibility of manipulating the functionality of an array of materials through advances in nanoscale engineering (Baird and Shew 2004). Eric Drexler captured some of the more extreme possibilities and ideas of developing materials and devices in his book “Engines of Creation” when he envisaged a doomsday scenario of self-replicating ‘nanobots’ turning life into ‘grey goo’ (Drexler 1987). However, real developments in nanotechnologies around the world began when in 2000, then U.S. President, Bill Clinton, launched the National Nanotechnology Initiative (NNI) and announced a US$225 million budget for nanotechnology R&D for fiscal year 2001, an 83% increase from the previous year (National Science & Technology Council 2000). This set the stage for an increasing number of nations investing in R&D of nanotechnologies (Renn and Roco 2006, p.21).

Nanotechnology is considered one of the most powerful “transformative” technologies of human history and the 21st century (Tegart 2004; Nordmann 2004; Sahoo 2013), and is often said to be an enabling technology (PMSEIC 2005; Fleischer and Grunwald 2008; Swierstra and Rip 2007; Chaudhry, Scotter, et al. 2008), incremental (Wood et al. 2008), converging and heterogeneous (de Bakker et al. 2014), with huge possibilities of industrial revolution, societal enhancements and environmental remediation (Parandian et al. 2012). Nanotechnology is usually referred to as ‘nanotechnologies’ due to its inter-disciplinary nature, drawing from different areas of science and engineering - such as applied physics, chemical, mechanical and electrical engineering - and because it encompasses a range of tools, techniques and applications. However, while some scientists and researchers believe nanotechnology has resulted from the “convergence of the traditional fields of chemistry, physics and biology”, there is a debate among others about this aspect (Tegart 2004).

5 An R&D program established to coordinate efforts in nanoscale science, engineering, and technology across multiple agencies within the U.S. Government
Despite its importance, there is no general or internationally accepted definition of nanotechnologies (Tachikawa 2012; OECD and NNI 2013; Ferrari 2010; Roco 2007; Which? 2009). While operational definitions are developed at national or regional levels, these are for “convenience, not of science” (Maynard et al. 2011). There are also proposals to altogether avoid a unique definition (Maynard 2011). However, some believe that a definition is urgently needed (Which? 2009, p.8) for the purposes of labelling, and which would also support industry and regulators in identifying necessary safety assessments (Stamm 2011).

Nevertheless, nanotechnologies have been described as the new industrial revolution (Holm 2014; Parandian et al. 2012; Roco 2001) which will represent a whole new method of manufacturing at the miniscule atomic level rendering many existing technologies and processes obsolete, while enabling an entirely new range of products and applications. The economic potentials and societal promises of nanotechnology have led many governments and companies to invest in this new technology (Purushotham 2012, p.26).

As increasing investments are made, there have been many new and interesting developments in nanotechnology in various areas, including consumer products, ICT, defence, medical, cosmetics, aerospace, transport, food and agriculture. According to a market research firm, Lux Research⁶, revenues from nano-based products has increased from US$339 billion in 2010 to US$731 billion in 2012 (Lux Research 2014) and this is predicted to increase to US$1 trillion by the year 2015⁷ (Roco and Bainbridge 2001; Roco et al. 2010; Cientifica 2007) and US$3 trillion by 2020 (Roco et al. 2010, p.61)⁸. In BRICS economies, the market for nanotechnologies is estimated to be about US$1 billion (Purushotham 2012, p.24).

Various non-official product inventories, such as the Wilson Center for International Scholars, Project on Emerging Nanotechnologies (PEN) in the USA⁹ (PEN 2010), the National Institute of Advanced Industrial Science and Technology (AIST) consumers product inventory in Japan¹⁰, NANOinventory launched by the EU, the inventory by the European Consumers Organisation (BEUC 2010), that have emerged over the years provide an insight to an array of

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⁶ An independent research firm that provides trends and intelligence on emerging technologies
⁷ Cientifica (2007) estimated that by 2015, the market for nanotechnology products will be over one trillion US$ in the US alone.
⁸ Lux Research predicts an increased revenue of $4.4 trillion by 2018
⁹ www.nanotechproject.org/inventories/
¹⁰ www.aist-riss.jp/db/nano/
products with a component of nanotechnologies that have proliferated markets around the world. The Nanowerk’s Nanomaterials database\(^\text{11}\) also provides a record of nanomaterials and products produced by suppliers worldwide.

Nanoparticles are appearing in almost all consumer products from clothes to toys to cleaning agents to cosmetics to edible items. The scope of potential applications of nanotechnologies and their economic impact can be far reaching and studies by various agencies and consultancy groups are predicting a ‘nano boom’ across a range of industries and sectors (Sengupta and Sarkar 2015).

However, some researchers argue that “nanotechnology still lives mostly on promises and visions” (Kearnes and Rip 2009, p.2). While some believe in the potentials of nanotechnologies, others believe it is over-hyped (Stang and Sheremeta 2006) and is “more of a dream than reality, more fiction than fact” (Selin 2007). Investors too are apprehensive about nanotechnology, whether there is actually a market with attractive benefits, or is it just another case of a dot com-like bubble (Loveridge et al. 2008).

2.2.2 Nanotechnologies for social and economic development

Discussions on nanotechnologies have leaned towards common goals – that of meeting societal grand challenges such as alleviating poverty, lowering carbon footprint, protecting the environment, providing access to clean drinking water, and treatment of terminal illnesses such as Cancer and Ebola, etc. In recent years, an increasing number of literature and reports have emphasised that innovation in nanotechnologies can be a solution to achieving the MDGs set by the UN in 2000, and lead to social and economic benefits (Todd Barker et al. 2005; Salamanca-Buentello et al. 2005; Roco et al. 2011). Nanotechnology is being developed worldwide with the aim of improving human lifestyle and economic growth. The future of nanotechnology is thus being seen not only to provide economic benefits (“material progress”) but also social and environment benefits (“moral progress”) (Roco et al. 2011, p.3559).

The potentials of nanotechnology are expected to bring many geographical regions to be involved in nanotechnology R&D (Shapira and Youtie 2012; Roco et al. 2011), with much of

manufacturing capabilities envisaged to move to Asian countries (Roco et al. 2011, p.3558).
Those that are likely to benefit most are developing countries and emerging markets that see
nanotechnology as a potential to provide solutions for the grand challenges that exist within
the country and region.

Nanotechnology is increasingly being given a high national priority in developed countries
and emerging economies (Renn and Roco 2006, p.88). Moreover, in order to feed a growing
world population, it has become essential to advance scientific and technological development
in developed and developing countries (Floros et al. 2010). There has especially been a growing
interest on the possible benefits of nanotechnology that could help reduce the gaps between the
developed and developing worlds (NIA 2013; Roco 2006). Many studies on the prospective
applications of nanotechnologies in the social, environmental and economic development of
developing countries have been carried out (Salamanca-Buentello et al. 2005). As early as
2005, Fabio Salamanca-Buentello et al. proposed ten applications of nanotechnologies that
could help in achieving the eight UN MDGs between 2004-2014, including applications in
agricultural productivity enhancement, water treatment and remediation, food processing and
storage. According to them the funding for these projects will come from national and
international foundations and collaborative projects.

However, the concept of ‘nanotechnology for the poor’ (Todd Barker et al. 2005), put forward
in early 2005 by Fabio Salamanca-Buentello et al. was challenged by Invernizzi and Foladori
(2005) who pointed out that the reasons for applying nanotechnologies in poorer countries -
that of doing minimal work, applications in agriculture for greater production outputs, less use
of material etc. – could actually be harmful and disruptive for poorer countries that have cheap
labour, natural resources and land. Moreover, in developing countries, poverty plays a big role
and basic needs of human beings are essential to the development of the nation. Thus, pumping
in money towards a new and emerging technology can be burdensome for poorer countries
(Ramani et al. 2010b, p.3) and create further disparity between the rich and poor countries
(Invernizzi and Foladori 2005, p.101). However, despite such scrutiny, recent research shows
that developing countries and emerging markets are already harnessing nanotechnologies and
nano applications are already being developed and used in developing countries like India and
South Africa, for combating many crucial problems that confront developing nations (Cozzens
et al. 2013; Beumer and Bhattacharya 2013).
2.2.3 Nanotechnologies in food and food packaging

One of the areas where nanotechnologies is expected to impact and grow radically is in the F&FP industry, including agriculture (Sanguansri and Augustin 2006; Chaudhry, Scotter, et al. 2008). At all stages of its production, from its use in enhancement of crop efficiency to its use in intelligent packaging, it is perceived that nanotechnologies will change the way food is grown, produced, processed, manufactured, packaged, transported, stored, monitored, consumed and disposed.

The opportunities for the application of nanotechnology in the agriculture and food industry was first addressed by the United States Department of Agriculture in September 2003 in a report “Nanoscale science and engineering for agriculture and food systems” (Scott and Chen 2003). In 2010, the UK House of Lords Science and Technology Committee, in their report “Nanotechnologies and Food”, envisaged explosive growth in nanotechnology in the food industry (House of Lords 2010a).

Since the publication of these reports, there has been substantial increase in investments for R&D of nanotechnologies in F&FP (Dudo et al. 2011). Many leading brands, such as Altria, H.J. Heinz, Kraft Foods, General Mills, Hershey, Nestle, Mars, Unilever, Smucker’s (SJM) and Albertsons Nestle have been known to have invested millions into the R&D of nanotechnologies in food (CORDIS News 2009; Which? 2009; Cientifica 2007; ETC Group 2004; Joseph and Morrison 2006).

Furthermore, in a global market where competition is steep and innovation is vital (Porter 1992), the potential application of the technology in food, beverage and packaging has generated much interest from companies worldwide, that are constantly looking for new, innovative and ‘intelligent’ ways to grow, process and package food efficiently and gain “competitive advantage and market share” (Cushen et al. 2012, p.30). Nanotechnologies has emerged as an “aid to advances in the production of improved quality food with functionalised properties” (Cushen et al. 2012, p. 30).

The proposed applications of nanotechnologies in F&FP is wide and varied and includes improving health food such as nutritional supplements, food textures, food safety, tastes, preservatives and packaging to prolong the shelf-life of food, fruits and vegetables; detect
pathogens and reduce spoilage; interactive foods with desired nutrition, colours and flavours, purification and treatment of water, food storage and detection of contaminants in crop (Tachikawa 2012; Bouwmeester et al. 2007; Cushen et al. 2012; Kuzma et al. 2008; Buzby 2010; Kuzma and VerHage 2006; Chaudhry, Scotter, et al. 2008; Chau et al. 2007).

For illustration purposes, Figure 2 provides a visual depiction of how an emerging technology, such as nanotechnologies, enters at different points of the food chain - from its research and development, manufacture and processing to distribution/commercialisation, market entry to waste/recycling - and provides some pertinent examples of the use of nanotechnologies in dairy products.

Many F&FP products with a component of nanotechnologies have already entered the market (Illuminato 2014; OECD 2013; Chaudhry, Scotter, et al. 2008) and Asian countries are expected to lead in nanofoods (Helmut Keiser 2003). In their Project on Emerging Nanotechnologies (PEN), the Woodrow Wilson International Center for Scholars has identified 117 known nano-food and beverage products or food-related products in the market that use nanotechnology. 15 of these were listed as used in cooking/kitchenware, 7 in food/beverage, 20 under food storage/packaging, and 69 for dietary supplements and this is expected to grow.

It is still uncertain, however, how many more products are already floating in the market (House of Lords 2010a, p.13) due to lack of product registries and product labels. A recent report by Friends of the Earth (FoE) noted that there are ten times more nanofood products in the market than there was six years ago (Illuminato 2014, p.4). Moreover, nanomaterials and nanofood-related products are also easily available for purchase over the internet (Which? 2009; Kuzma and VerHage 2006).

In food packaging (FP), nanomaterials are increasingly being used in several applications: improved packaging for flexibility, strength, temperature/moisture stability, where nanomaterials are mixed with polymers to enhance gas barrier properties and to keep PET (polyethylene terephthalate) bottle shatter-proof; active packaging with antibacterial properties, where nanomaterials are used to detect food spoilage and alert consumers and retailers when food is spoilt; and intelligent/smart packaging such as nano-sensors to detect

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12 See www.nanotechproject.org/consumerproducts
13 As of 26 February 2015, though upon scrutiny some of these products were not in production any more
food pathogens (e.g. Salmonella and E.coli) or as tracing device; biodegradable polymer-nanomaterial composites such as nanocomposite films for improving mechanical and barrier properties to increase shelf-life of packaged food products (Silvestre et al. 2011; Duncan 2011a; Chaudhry, Scotter, et al. 2008). Nanotechnologies are also being used to develop solutions to authenticate products and combat counterfeit of branded products such as wine (Kim et al. 2014). Thus, the potentials of nanotechnologies in F&FP are vast and varied.

2.2.4 Risks, uncertainties and gaps

Despite increasing R&D investment, by public and private sectors, including small and large firms (Robinson and Morrison 2010), and proliferation of nano-enabled products in the market (see Appendices 3, 4, 5, 7 & 8), many concerns have been expressed about the negative effects (actual or perceived), such as EHS risks and ELSI aspects related to nanotechnology. This unease was reflected in an early report by the Royal Society and Royal Academy Engineering (RAE) in the UK, in 2004. The report raised serious concerns about the health and environment risks posed by nanotechnologies and reported the need for regulation (The Royal Society & Royal Academy of Engineering 2004). A more recent report by the World Economic Forum (WEF), based on an extensive survey of over 1,000 experts worldwide, identified the likelihood and impact of unforeseen consequences of nanotechnology as potential risk in the next ten years (World Economic Forum 2013).

Nanotechnology has unique biological, physical and chemical properties (because of its larger surface area to volume ratio\(^\text{14}\)), which are substantially different to similar elements in its macroscopic/bulk form (The Royal Society & Royal Academy of Engineering 2004; Renn and Roco 2006; NNI 2014; Gruère 2012). A single nanomaterial may have different shapes and geometry, i.e. different nanostructures (See Figure 3), and thus may have different properties (European Commission 2015). For example, gold in its nano form appears as red or orange colour, instead of a gold colour (Tachikawa 2012, p.114). Due to these peculiarly unique properties, there is a huge scientific gap in understanding the behaviour of nanomaterials and a new

\[^{14}\text{That is, in a nanoparticle, the amount of surface area is larger compared to its volume}\]
**Figure 2: Nanotechnologies at different points within the value chain of dairy product**

**GOVERNANCE OF NOTECHNOLOGIES WITHIN THE FOOD CHAIN**

Source: Author

- **Pasteurisation:** changes the size of particles, reducing them in size or causing them to agglomerate.
- **Homogenisation:** fat emulsion is broken down or reduced to the size of the fat globules found in milk or cream.
- **Nano-sensors:** ‘smart packaging’ – for traceability & contaminant detection during transportation & storage e.g. colour change in packaging when milk is spoil.
- **Packaging reflects heat to keep ice cream frozen in a hot car.**
- **Smart packaging:** nanoclay keeps food fresh for months by blocking the passage of oxygen & moisture, & slowing growth of bacteria.
- **Mayonnaise:** Low-fat, full flavour, nano-structured mayonnaise.
- **Non-stick nano lining thin film on inner side of bottle helps to remove mayonnaise easily.**
- **Ice-cream with lower fat content but same fatty texture & flavour as full fat ice-creams.**
- **Cheese:** nano-particles of protein stick together to form gels which give it a special texture.
- **Nano-emulsions used to reduce fat (WOW).**
- **Nanoencapsulation e.g. Interactive foods - allows consumers to modify foods depending on their taste and nutritional needs.**
- **Hot to keep ice cream frozen in a hot car.**
- **Packaging reflects heat to keep ice cream frozen in a hot car.**
- **Nano-sensors:** ‘smart packaging’ – for traceability & contaminant detection during transportation & storage e.g. colour change in packaging when milk is spoil.

- **Raw milk:** An emulsion of fine fat droplets of nanoscale proportions: small particles of protein suspended in water.
- **Milking:** Nanochips: track, identify & monitor cow; deliver measured quantities of vaccines for treatment of disease.
- **“Smart” pesticide delivery, control of crops, animal health, control of microbial & chemical contamination & plant.**
- **Feed:** Nanomaterials may enter animal feed through waste food or environmental sources.
- **Disposal:** Food and Packaging Waste: Manufactured nanomaterials released into the environment from waste streams.
- **Purchasing:** Consumers purchase nano-products in retail stores or restaurants.
- **Retailing:** Nano-encapsulation e.g. Interactive foods - allows consumers to modify foods depending on their taste and nutritional needs.
- **Manufacturing:** Nanoparticles added to upgrade texture of ice-cream.
- **Packaging:** Smart packaging: nanoclay keeps food fresh for months by blocking the passage of oxygen & moisture, & slowing growth of bacteria.
- **Anatase TiO₂ used as a whitener additive.**
- **Nano-emulsions used to reduce fat (WOW).**
- **Manufacturing:** Ice-cream with lower fat content but same fatty texture & flavour as full fat ice-creams.
- **Packaging:** Smart packaging: nanoclay keeps food fresh for months by blocking the passage of oxygen & moisture, & slowing growth of bacteria.
- **Mayonnaise:** Low-fat, full flavour, nano-structured mayonnaise.
- **Non-stick nano lining thin film on inner side of bottle helps to remove mayonnaise easily.**
Figure 3: Nanostructures of gold nanomaterial with different shapes and geometry


toxicological approach is needed, which is different from classical approaches.

However, nanoscale materials such as zinc oxide (ZnO$_2$), titanium dioxide (TiO$_2$) and silver nanoparticles (AgNPs) are used in various nano-products (Chaudhry et al. 2008, p.246). While the former two are commonly used in personal care products like sunscreens to block ultraviolet and in toothpaste as a whitening agent, the latter is used in medical gloves and FP as an antibacterial. Nano-scale TiO$_2$ is also used in food and other colour additives (e.g. white food additives) by companies and can be found in many candies, chewing gums and dairy products (Weir et al. 2012; APCTT-ESCAP 2010).

There is a growing body of scientific evidence that have indicated that nanoparticles can penetrate human skin and cells, and cause harm (Behar et al. 2013; Maynard 2006; Maynard 2012; Illuminato 2014; Nazarenko et al. 2012) due to its small size (Verano-braga et al. 2014).

It is believed that when macro materials are reduced to nanoparticles, they are highly unstable or ‘bioactive’ due to its unimaginably small size and large surface area. These nanoparticles have the propensity to enter the blood from where they can penetrate the liver, spleen, bone marrow, heart, and other organs (Oberdörster et al. 2005) or the central nervous system and thus affect cardiac and cerebral functions (Donaldson et al. 2004).
Nanoparticles, especially those in powder form, are also said to agglomerate within the human body and remain as toxic containments causing harmful diseases (Chau et al. 2007; Cushen et al. 2012) such as Alzheimer’s and Cancer. Nanomaterials such as nanosilver (commonly used for its anti-bacterial properties), when used in food products is said to be highly active and are able to easily penetrate or be absorbed through the human skin and intestine cell walls due to its small size (Chau et al. 2007; Verano-braga et al. 2014). Various studies have also shown the migration of anti-microbials, like nanosilver, from nanocomposite packaging into food, especially when microwaved (Echegoyen and Nerín 2013; Cushen et al. 2014).

Risks due to exposure in children are considered to be higher (e.g. baby bottles, pacifiers containing nanosilver as antibacterial material) (Chaudhry 2012; CCA 2008; Senjen and Illuminato 2009). A study found that children were quite vulnerable to risks of nanotechnologies as they had the highest exposure to TiO$_2$ because of a higher content of TiO$_2$ in sweets and chewing gums than adult products (Weir et al. 2012, p.2243).

Nanotechnologies have also been compared to asbestos (Greenemeier 2008). A study showed that carbon nanotubes with distinct needle-like fibre shape (similar to asbestos) have been shown to cause inflammation and lesions in lung tissues in mice (Poland et al. 2008, p.424).
Recent exposure to nanoparticles in the workplace in China have shown pulmonary inflammation and fibrosis in the lung tissue causing two deaths and severe disability of workers (Song et al. 2009; Song et al. 2011).

However, amidst these fears, some researchers have also ruled out any significant health threat of nanomaterials. A study on pigskin found that there was no significant penetration of TiO$_2$ nanoparticles; thus concluding that nanoparticles in sunscreens is unlikely to penetrate human skin (Sadrieh et al. 2010). Another study with rats did not show evidence of toxicity in terms of oxidative stress and inflammation when exposed to nanocomposite in water (Maisanaba et al. 2014).

Thus, there are conflicting evidences on the risks of nanotechnologies.

Despite these uncertainties, many nano-based products are already being developed and placed in the market. Moreover, the emergence of nano-based products is much faster in comparison to the available EHS data and their subsequent use and analysis by government agencies, who have limited resources (Linkov et al. 2009) (see Figure 4). A reliable, rational and responsible approach is thus needed to understand the potential impacts of nanotechnologies (Renn and Roco 2006; Cushen et al. 2012). Much more scientific research will also be required to ascertain the safe use of nanotechnologies (Steffen Foss Hansen et al. 2008). However, because of its complexities, research can be expensive and time-consuming (Lee and Jose, 2008, p.116). On the other hand, since there is much uncertainty about the risks of nanotechnologies, and nor has there been a case where it has been seen to be harmful to humans or environment (Tachikawa 2012, p.114), there is a view that risks of nanotechnologies could all just be based on “unproven assumptions” or speculations (Wood et al. 2008). However, the scars left behind by Bovine Spongiform Encephalopathy (BSE)$^{15}$, biotechnology, GMO and asbestos (Rogers-Brown et al. 2011; Roco et al. 2011), have left the general public with the notion that nanotechnologies are dangerous and brings fears among consumers about potential adverse impacts, both in the short and long term, thus creating major challenges in transferring technology from laboratory to marketplace.

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$^{15}$ Commonly known as Mad Cow disease
2.2.5 Governance of nanotechnologies

2.2.5.1 Regulation of nanotechnologies

The diversity, scale and varied properties of nanotechnologies pose significant challenges for regulation. The main problem in regulating nanotechnologies relates to the uncertainty in the behaviour of nanomaterials at the nanoscale (Steffen Foss Hansen et al. 2008; Lee and Jose 2008) and the current state of knowledge is insufficient to establish regulations. There are two important aspects to this – that of nanomaterials small size (nanoscale); and risks, which are still unknown. The uncertainties of the risks of nanotechnologies are further intensified due to the absence of suitable testing methodologies/assessments, which has led to delays in regulation. While there are calls to establish testing protocols to ensure the safe manufacture and use of nanomaterials (Nel et al. 2006), the scientific and regulatory uncertainties of nanotechnologies has led many experts to caution use of nanomaterials until further information is gained (Chau et al. 2007, p.277).

However, innovations in nanotechnologies are emerging faster than regulation being brought in (Sahoo 2013; Roco et al. 2011). With EHS assessments of nanotechnologies lagging behind the pace of commercialisation (Tager and Sales 2014), various non-governmental organisations (NGOs) and civil society organisations (CSOs) have also been critical of the lack of available regulations and readiness of regulatory bodies with regards to nanomaterials and are calling for either a moratorium in R&D of nanotechnologies or development of nano-specific regulations (ETC Group 2003b; Miller and Senjen 2008; Tager and Sales 2014; MacKerron 2012; Behar et al. 2013; Arnall 2003; Galland and Passoff 2011).

Some companies, however, argue that it is too early to bring out policies for nanotechnologies (Kearnes and Rip 2009, p.6) as some of these materials have already been in use since decades and have been considered safe due to its history of use, e.g. micelle in milk (Sekhon 2010; Tachikawa 2012). Equally, reports on an assessment of potential risks associated with engineered nanomaterials have concluded that insufficient data and a knowledge gap to identify
the toxicological\textsuperscript{16} nature of nanoparticles prevent a thorough assessment of engineered nanomaterials (SCENIHR 2005).

In the absence of sufficient data, regulatory entities are reluctant to come up with new policies too soon. Moreover, with new information on nanotechnologies the perceptions and realities of risks are constantly changing and thus it is becoming more difficult for regulatory bodies to create a standard regulation for nanotechnologies.

Also, coming up often in the debates on nanotechnologies are whether there is a need for a specific regulation for the technology. The report by the Royal Society and Royal Academy of Engineers in 2004 deemed that it was unnecessary for a separate regulator or regulatory framework for nanotechnologies as existing regulations were “sufficiently broad and flexible to handle nanotechnologies” (The Royal Society & Royal Academy of Engineering 2004, p.11). They also pointed out, however, that existing regulations may need to be reviewed for its adequacy as a precautionary measure due to the fact that the toxicity of nano-sized particles may be more as compared to its larger form (e.g. carbon and carbon nanotubes) (p.12). This was also supported by the OECD, in its report, which stated that due to the technology’s interdisciplinary nature, a general “nanotechnology policy” would not be an ideal approach (OECD 2010b). Thus, the adaptation of current regulatory frameworks have been considered to be sufficient for nanotechnology governance by many countries (Kearnes and Rip 2009; Pelley and Saner 2009; Tachikawa 2012; Roco et al. 2010; FSCJ 2010; Kurath 2009; TERI 2009b) and there are no existing policies or specific legislations for regulating nanotechnologies (Siegrist and Keller 2011; Chaudhry, Scotter, et al. 2008).

However, the traditional mechanisms for regulation of products are not sufficient either to regulate novel nanotechnologies. While some materials (e.g. silver and gold) are currently covered under existing statutes, these are meant for their conventional (larger) equivalents, though, size alone cannot be used as an indicator for classification of nanomaterials (Tachikawa 2012, p.115).

\textsuperscript{16} The U.S. Society of Toxicology defines toxicology as “the study of the adverse effects of chemical, physical and biological agents on people, animals and the environment
This absence of sufficient knowledge and the novelty of nanoparticles exposes the market to a plethora of products that are unregulated and which potentially escape regulatory scrutiny and lead to a reduction of assessment of the products (Lee and Jose 2008; Widmer et al. 2010).

The inaction by various governments on regulatory issues is partly also because there has been no catastrophe or health issues that have compelled them to take immediate decisions on regulations (Tachikawa 2012, p.117). Furthermore, none of the countries have categorically stated that nanotechnology is characteristically safe or harmful. Instead, many governments in developed and developing economies, are playing a ‘waiting game’ and monitoring the regulatory movement of advanced countries like the U.S. and EU (Tachikawa 2012, p.114).

The question, however, is not just how to regulate, considering the uncertainties surrounding this emerging technology, but when to regulate. There is the dilemma in regulating “neither too early nor too late” (Silva and Robinson 2012; Randles 2008). Bringing in regulation when there is uncertainty could result in the moratorium of nanotechnologies. On the other hand, if one waited for a disaster to happen, it could result in unsafe use and distribution of nano-products. Lee and Jose (2008) believe that a formal regulation will take time to implement mainly because of the learning curve involved in understanding the social aspects of the technology and the complexities involved in adapting regulatory structures as mechanisms of control (p.116). While there is stress on the need for a precautionary principle (PP) approach (Chau et al. 2007, p.277), which will allow for “tailored safeguards” for “hypothesized threats” (Lee and Jose 2008, p.114), it is also believed that it could stifle innovation given that some of the free nanomaterials, which are currently harmless, will then be subjected to regulation.

The uncertainty of risks and the trajectory route of nanotechnology has led to new suggestions of adaptive and anticipatory frameworks of governance to be identified and put in place by governments (Roco 2006; Barben et al. 2007).

**2.2.5.2 Anticipatory approaches through voluntary and soft laws**

In the absence of policies and under uncertain risk environments, regulation involving broad anticipatory governance, including ‘hard’ (legal authority) and flexible ‘soft’ (not legally binding) regulatory approaches, has emerged over the years, at both, the national and international level (Grobe et al. 2008; Roco et al. 2011) as strategic attempts to address the
‘too early/too late’ dilemma (Kearnes and Rip 2009, p.6). These include legislation, risk assessments, EHS and ELSI research, public engagement/surveys, codes of conduct (such as UK’s Responsible NanoCode, EU’s Code of Conduct for Responsible Nanosciences and Nanotechnologies Research, Swiss Code of Conduct: Nanotechnologies), best practices, guidelines, standards and certifications (such as the CENARIOS® safety certifications for companies17), and voluntary/mandatory reporting schemes.

International governance approaches such as the International Standards Organisation (ISO) TC-229, International Electrotechnical Commission (IEC) and OECD’s Working Party on Nanotechnologies (WPN) are other examples that are adopting anticipatory governance approaches for the governance of nanotechnologies on a transnational level. As guidelines for organisations and other stakeholders to develop nanotechnologies ‘responsibly’, these voluntary codes are considered a useful complement to regulation (Malsch 2009, p.17) and are used in anticipation that a more formal regulation will be developed for nanotechnologies in future (Kearnes and Rip 2009, p.117).

However, while these soft and (informal) hard laws are being attributed to the development of nanotechnologies through accountability, safety, acceptance, trust and notions of responsibility (Kurath 2009, p.88), they have largely resulted in problems of compliance and implementation (Dorbeck-jung 2011). According to Sutcliffe, as voluntary mechanisms, such anticipatory governance raise “issues of legitimacy and effectiveness” (Sutcliffe 2011). Some of these approaches, such as the voluntary reporting/disclosure schemes that were introduced (e.g. by DEFRA-UK18 and the US EPA19) are also said to have had “limited impact” (Roco et al. 2011, p.3560) and not very successful (Senjen 2009, p.3). Forloni (2012) has pointed out that unless these voluntary codes become mandatory they will fail to reduce risks and public concerns. However, more recently, some developed economies have resorted to mandatory reporting and registry for the use of nanomaterials (e.g. France20, Belgium21, Denmark22) (Commission 2014)

17 The world’s first nanotechnology safety certificate, developed by the Innovation Society
19 Nanoscale Materials Stewardship Scheme Under the Toxic Substances Control Act (2008)
20 Declaration of Nanomaterials (2013)
21 Operational in January 2016
22 Environment Protection Agency finalised the scheme (2014), the deadline of which is on 30 August 2015
2.2.5.3 Labelling nano products

There are various demands for labelling of consumer products, including nanofood and other consumer products (ETUC 2008; Throne-Holst and Rip 2011). However, adopting a mandatory labelling system in the absence of sufficient scientific data would be premature (Mehta 2004) and expensive (Tachikawa 2012, p.115) and would very likely raise price of food products and come at a cost to consumers, as has been the case with GMO (Flynn 2014). Moreover, some critics believe that labelling would not reduce the risks affiliated with nanotechnology use or disposal of products (Adler 2012). We have also seen from the GMO case that precautionary measures of labelling emerging technologies used in food has resulted in public backlash. However, by not labelling, there are still new demands for labelling of emerging technologies, though so far these have failed in the U.S. (Falkner et al. 2009).

In December 2013, ISO developed a guidance for voluntary labelling of consumer products (ISO/TS 13830:2013) incorporating nanomaterials (ISO 2013). So far these have not as yet been utilized by organisations.

2.2.5.4 ‘Responsible’ development of nanotechnologies

There are suggestions that the hype, economic motivations and shareholder interests have sidelined the issues of nanotechnologies and the discussions on nanotechnologies by governments are often more leaned towards R&D and economy competitiveness (Hansen et al. 2008).

In the past decade, with growing concerns of the EHS implications of nano-engineered materials, the debate on nanotechnologies has grown to focus on discourses of the ‘responsible development of nanotechnology’ and governance of this emerging technology. Initially, risk management and technology assessments (TA) were seen as an approach to address the safety issues of nanotechnologies, where the focus was on the “negative consequences” and “adverse effects” of technology (von Schomberg 2012). More recently, increasing interest and attention are being given to the emerging concepts of ‘responsibility’ as an approach to deal with the issues and impacts of emerging technologies, where risk and risk analysis has failed to work (McCarthy and Kelty 2010). However, ‘responsibility’ in nanotechnology is a “vague and polyvalent” idea (McCarthy and Kelty 2010, p.406) and needs further investigation.
The discourses on the ‘responsible’ development of nanotechnology have been reflected in many reports and literature (OECD 2009; Forloni 2012; Schulte et al. 2014; ETUC 2008; Doubleday 2007; Widmer et al. 2010; Tomellini and Giordani 2008) and has become part of many government strategies (NNI 2014; OECD WPN 2013) and forums (GAO 2014). Deliberations on nanotechnology governance have grown to incorporate EHS and ELSI issues of nanotechnologies (Roco et al. 2011, p.3558) and various guidelines are being formulated (Carthy et al. 2013) on a national and international level to address the social and ethical implications of nanotechnologies (Lee and Jose 2008, p.117). Funding is also being allocated to help address the issues of EHS and ELSI.

The formation of various government-funded institutes – such as Rice University's Center for Biological and Environmental Nanotechnology (CBEN) and the International Council on Nanotechnology (ICON), and the University of California’s Centre for Nanotechnology in Society (CNS-UCSB) - to study the risks of nanotechnologies are also growing. Further, in February 2015, the U.S. Consumer Product Safety Commission (CPSC) submitted a request for US$5 million increase to the agency’s existing nanotechnology work, to establish a Center for Consumer Product Applications and Safety Implications of Nanotechnology (CPASION) (CPSC 2015). The rise in various conferences on the ‘responsible’ development of nanotechnologies around the world over the years are also reflections of the growing importance given to the environmental impacts and health effects of nanomaterials.

More recently, there has been a growing emphasis on responsible innovation (RI), mainly directed and focused towards new and emerging technologies (Blok and Lemmens 2015). The European Commission has elaborated on incorporating ‘responsibility’ in terms of research and innovation design strategies for the achievement of societal needs and values (von Schomberg 2013). This idea has been extended to a Responsible Research and Innovation (RRI) framework within the EC’s Horizon 2020 programme23 where the focus is on ‘grand challenges’ and societal objectives (von Schomberg 2013). Several projects within the EU have been devoted to explore RI24 (Euroscientist 2014).

23 A new seven-year research and innovation initiative of the European Union
24 Examples include Responsibility: Global Model and Observatory for International Responsible Research and Innovation Coordination; Responsible Industry; FaRInn (Facilitating Responsible Innovation in SEE countries); GREAT (Governance for REsponsibleinnovATion); KARIM (Knowledge Acceleration Responsible Innovation Meta-network); ENGAGE; CONSIDER (Civil society OrgaNisationS In Designing rEsearch governance); ResAGorA; PROGRESS; RRI Tools; UK’s EPSRC; Netherland’s NOW; etc.
While gaining importance in Europe, this new aspect of RI is slowing gaining importance among policy-makers, governments and practitioners. According to Kurath (2009), these concepts are seen as a substitute for federal regulation where they can lead to more strong science and technology policy (p.100), while also providing guidance for scientists, researchers, organisations, regulators, policy-makers and various other actors in their roles in the R&D of innovation and novel technologies. (A more detailed reflection of RI is discussed in Chapter 3).

The notions of ‘responsibility’ or ‘responsible’ development of nanotechnology also involves the inclusion of various interested parties, including academia, research institutes, industry, scientists, governments, NGOs, financial institutions and general public at the national and international level (European Commission 2008; Insight Investment et al. 2008). These actors make an effort to develop appropriate mechanisms and governance strategies to address the complex issues of nanotechnology (Forloni 2012, p.1). This process of democratization, as part of ‘responsible’ development of nanotechnology, has shifted the regulatory responsibility to the actors involved in R&D, manufacture, retail and disposal processes of nanotechnologies. Furthermore, with growing global market complexities, involvement of a heterogeneous group of actors and change in societal norms (Bakker et al 2014), ‘responsibility’ has moved from being individual (traditionally) to collective (modern) (McCarthy and Kelty 2010, p.408). Collective responsibility is for both, the positive and negative impacts for new technologies, whether these are intentional or unintentional (von Schomberg 2013). It is thus essential to involve the perspectives of government, industry, non-governmental organisations and civil society organisations (CSOs) in debates on nanotechnologies (Roco 2006, p. 12). However, Kurath (2009) believes that by entrusting techno-political decision-making to a variety of actors through such governance approaches, it may lead to a vacuum in S&T policy (p.102).

### 2.3 Nanotechnologies in Canada

The following sections focus on Canada. It provides a primary overview of nanotechnology R&D in Canada, the availability of funding and the regulatory frameworks in place. It examines policy and legal instruments, the existing institutional frameworks for F&FP and the schemes for public participation in policy debates. A more detailed profile of Canada’s involvement with nanotechnologies has been presented in Appendix 12.
2.3.1 Regulation relevant to the governance of nanotechnologies in Canada

While Canada does not have a specific policy for nanotechnology (OECD WPN 2013) the Government of Canada (GoC) has many policies that deal with the health and environment risks in consumer products. However, many of these are not designed to regulate nano-products (Nielsen, 2008). A 2008 OECD WPN Report outlined that Canada did not create new strategies to support nanotechnology development but followed existing policies and strategies. Thus, Canada uses its current regulatory frameworks for non nano-based products to regulate nanomaterials but expects to enhance these as new developments in the technology occur and new requirements arise in future (Nielsen, 2008, Pelley and Saner, 2009).

In a 2008 report, the Council of Canadian Academics (CCA), a not-for-profit organisation in Canada involved in scientific assessments of materials, recommended that while the existing regulatory approaches and risk management strategies are sufficient for monitoring nanomaterials, much investment is required for research in risk assessment (CCA 2008). The Canadian Institute for Environmental Law and Policy (CIELAP) in their Nano Policy Framework document in 2008 recommended banning nanomaterials in all F&FP products and labeling other products with nanomaterials. Both these recommendations resulted in contentious debates and subsequent rejections (Holtz 2008).

In Canada, the regulation of diverse consumer products is managed at the federal and provincial levels (Nielsen, 2008). Food is regulated at both the federal and provincial levels. However, Environment Canada (EC) and Health Canada (HC) are the two main agencies that share responsibility for the regulation of nanomaterials that are manufactured or imported into Canada. EC focuses on risks to the environment, while HC focuses on risks to human health. As the Acts and Regulations administered by HC has no explicit reference to nanomaterials, HC adopted an Interim Policy Statement on Health Canada's Working Definition for Nanomaterials in October 2011 (OECD WPN 2011). This interim policy was established in consultation with international stakeholders, governments and other Canadian government departments, companies, industry trade bodies, standards associations, academia, public interest groups and interested citizens. The objective of the interim policy, though broad, was to get information on the existing products and substances using or containing nanomaterials in order to be able to establish guidance for policy development. It provides a working means
of identifying nanomaterials in order to “improve the understanding of nanomaterials for risk assessment and risk management purposes”\(^{25}\).

Other federal agencies that also monitor activities surrounding the R&D of nanotechnologies are Industry Canada (IC), National Institute for Nanotechnology (NINT), Department of Foreign Affairs & International Trade Canada, National Research Council (NRC) Canada and the Natural Sciences and Engineering Research Council (NSERC) of Canada.

### 2.3.2 Regulating food and food packaging

In Canada there are three main federal agencies involved in regulating F&FP products: HC, which is the policy and standards setter, the Canadian Food Inspection Agency (CFIA) (part of the Department of Agriculture and Agri Food Canada), which is the policy and standards enforcer, and EC, which is responsible for evaluating new substances.

HC is the main regulatory body responsible for regulating products and substances, which include natural health products, F&FP, new and existing substances, besides others\(^{26}\). The application of nanomaterials in food is subjected to the same health and safety regulations as that used for conventional food products. Currently all food products are regulated under the Food and Drug Act and Regulations of Canada\(^{27}\). The Food Additives Regulation, Novel Foods Regulation, Natural Health Products Regulations and the Food Packaging Materials Regulation are other regulatory systems that are applied to food products using nanomaterials. Health Products and Food Branch (HPFB) of Health Canada is responsible for managing health-related risks and benefits of health products and food. While liaising closely with industry they help minimize risks and maximize safety of products.

The CFIA carry out inspection on F&FP for HC and administer the law set by them. Besides dealing with the regulatory aspect of nanotechnologies in food, CFIA deals with the registration of products that can be used in agriculture and food products. In October 2012, the Parliament


in Canada passed the Safe Food for Canadians Act (S-11)\textsuperscript{28} to help modernise and consolidate the current regulatory system in F&FP. This Act gave CFIA new powers and controls to inspect and enforce safety in Canada’s food supply. Under this regulation, importers are directly held accountable for the nature and safety of F&FP products exported into the Canadian territory. Importers are required to obtain a pre-requisite licence to import food products. They are also required to develop preventive food safety programmes such as assessing products being imported for any risks and informing their suppliers of the protocols under the Food & Drugs Act and the Consumer Packaging & Labelling Act for the safety of F&FP products sold in Canada.

The Agriculture and Agri Food Canada is the main agency responsible for regulating agriculture and agri-food products.

The Public Health Agency of Canada (PHAC) and the Canadian Border Services Agency are government agencies that are also responsible for food safety in Canada - those produced in Canada and those that are imported. The PHAC conducts surveillance activities to ensure the health and safety of Canadians. As surveillance overseers their responsibility is to look for potential hazards that might not have been recognised through earlier tests.

Nanomaterials are regulated through existing legislations such as the Canadian Environmental Protection Act, 1999 (CEPA 1999), the Pest Control Products Act, the Fertilizers Act, the Feeds Act and the Food and Drugs Act. The Canadian Environmental Protection Act, 1999 (CEPA 1999) is used to protect human health and environment and provides a “safety net” for assessing products and substances by requesting further information prior to their use (OECD WPN 2011).

Manufacturers and importers in Canada are required to notify the Food Directorate at Health Canada of the sale or advertisement of any novel products. Under Division 28, the Novel Food Regulation of the Food and Drug Regulation, all information pertaining to novel foods must be submitted to HC for assessment of the food product before it is sold or advertised\textsuperscript{29}. A list of

\textsuperscript{28} Canadian Food Inspection Agency (CFIA) website, Safe Food for Canadians Act: http://www.inspection.gc.ca/about-the-cfia/acts-and-regulations/regulatory-initiatives/sfca/overview/eng/1339046165809/1339046230549

\textsuperscript{29} Agriculture and Agri-Food website: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1171285739616&lang=eng
approved novel food products, including GM foods, can be found on Health Canada’s website\(^{30}\). A list of approved nanofood products were absent.

The Food Directorate’s Bureau of Chemical Safety in Canada is responsible for approving any additives in Canada, whether new or previously approved additives. All manufacturers are required to go through a pre-market safety assessment of substances by providing information on the substances used, including those containing nanomaterials to the Bureau before placing the product into market.

The responsibility for ensuring that food packaging materials do not contain chemicals or physical harmful substances that can penetrate into the food products lies with the manufacturers. A voluntary program is available for manufacturers to submit information on materials in packaging to the Food Directorate’s Bureau of Chemical Safety for a pre-market assessment. However, for novel food packaging products manufacturers and importers are required to get their products evaluated and approved by the CFIA for compliance with other legislation and certification programs.

### 2.3.3 International co-operation in regulation

The Standards Council of Canada (SCC) are responsible for studying the current standardisation gaps in different sectors in Canada, including emerging sectors such as nanotechnologies, and recommending standardisation solutions. While they do not write the standards, they are responsible for crediting various standards development organisations – such as The Canadian Standards Association (CSA), underwriters to the Board Rights Canada and The Canadian General Standards Board (CGFB). They facilitate any standardisation related relationships at the national and international levels. In an “An Action Plan” report in 2009, the SCC proposed nanotechnologies as one of the sectors that needed standardisation solutions. The Canadian Standards Association (CSA), a government funded standards writing organisation in Canada, was then allocated funding to develop standards in the area of nanotechnologies.

Canada is an active participant in various international nanotechnology working committees, including the OECD WPN, the ISO TC-229 and IEC TC113 technical committees to help develop internationally compatible approaches for the ‘responsible’ development of nanotechnologies (OECD WPN 2013).

The Resource Processing Industries Branch of Industry Canada leads the work program promoting international co-operation on policy dialogues on nanotechnologies and the ‘responsible’ development and commercialisation for the OECD WPN. Officials from HC and Statistics Canada are also active participants in the program, which also covers programs on food and health. The OECD Working Party on Manufactured Nanomaterials (WPMN) is represented by The Science and Technology Branch, Emerging Priorities Division of Environment Canada, and involves research on human health and environmental safety of manufactured nanomaterials, testing of manufactured nanomaterials for safety and applicability of existing test guidelines, identifying risk assessment issues, and alternative test methods and exposure measurement and mitigation, information gathering and regulatory programs.

In February 2011, a Canada-United States Regulatory Cooperation Council (RCC) 31 was created as a process of regulatory transparency and cooperation by the two governments to look at efficiency measures at the Canada-US border. Various sectors were included in the initial Joint Action Plan as priority areas for the two-year mandate. Agriculture, food (safety, certification, approvals, labelling, etc.) and nanotechnology (regulation, fostering innovation, addressing health and environment risks, identification of gaps) were also included based on inputs received from 170 32 stakeholder, such as the general public, companies, businesses and industry associations, regulatory departments and bodies, and different provincial regions. The group has invited initial voluntary submission of nanomaterials by organizations. Main departments and agencies of the GoC that are part of this working plan are the Foreign Affairs and International Trade, Industry Canada, Treasury Board Secretariat, Agriculture and Agri-Food Canada, Canadian Food Inspection Agency, Environment Canada, Health Canada and Transport Canada.

2.4 Nanotechnologies in India

This section focuses on India. It primarily provides a review of nanotechnology R&D in India and the regulatory frameworks in place. It examines the existing funding available for R&D in public and private institutes, as well as for risk assessments. A more detailed profile of India’s involvement with nanotechnologies has been presented in Appendix 13.

2.4.1 Research and development of nanotechnologies in India

The Government of India (GoI) plays a catalytic role in promoting nanotechnology in India (TERI 2009b; Purushotham 2012). In view of the economic importance and the opportunities that nanotechnology may bring to a developing country, both the State and Central governments in India have led and supported the R&D of nanotechnology through incentivised policy initiatives and funding of nanotech projects (Sharon 2013; TERI 2010a) across various sectors (Purushotham 2012), including food. Many of these have also been transferred to industry. Thus, nanotechnology R&D in India is mainly being carried out at government-led research institutions or universities and though there has been emphasis in public-private partnerships in India, private sectors have been slow in harnessing this new technology mainly due to lack of funds (TERI 2009a).

Various government agencies are actively involved in nanotechnology research (See Table 1). The national S&T policy agencies are vested with the prime responsibility for decision-making and implementation strategy for nanotechnology development and management. This includes the Department of Science and Technology (DST), the Department of Biotechnology (DBT), Council of Scientific and Industrial Research (CSIR) within the Ministry of Science and Technology, Department of Information Technology (DIT) within the Ministry of Communication and Information Technology, Indian Council of Medical Research (ICMR) within the Ministry of Health and Family Welfare, Defence Research & Development Organisation (DRDO) under the Ministry of Defence, Indian Council of Agricultural Research (ICAR) under the Ministry of Agriculture, Ministry of New and Renewable Energy,

33 Under Department of Scientific and Industrial Research (DSIR)
34 Under Department of Defence Research and Development
35 Under the Department of Agricultural Research and Education (DARE)
Ministry of Commerce & Industry, Ministry of Water Resources (MoWR), Ministry of Food Processing Industries (MoFPI), Ministry of Environment and Forest and Ministry of Textiles.

The DST is the chief government agency engaged in the development of nanotechnology, setting up various nanotech projects across India. In May 2007, N&N became a prime focus for the GoI after the launch of the five year Nano Mission (NM) plan, which specifically focused on providing safe drinking water using nanotechnologies, nanomaterials and sensor development, etc. The aim of the NM is to promote nanotechnologies research, develop infrastructure, applications and capacity, enhance international collaborations and organise national deliberations on nanotechnologies (GoI Annual Report 2013). Thus, a strategy has been put in place by the DST to fund projects incorporating nanotechnologies.

While the DBT supports research in nanotechnology and the life sciences, the CSIR engages in scientific and industrial R&D for socio-economic benefit and has also commissioned various projects in nanotechnology in diverse areas. The CSIR is the premier R&D organisation of India, with thirty seven labs, fifty nine field centres, three innovation complexes and five units, spread throughout the country (Serena Borgna et al. 2012). The Central Food Technological Research Institute (CFTRI) in Mysore, South India, set up about 60 years back, is the main centre that conducts research in food and food processing, including food packaging.

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<tr>
<th>GOVERNMENT DEPARTMENTS INVOLVED IN NANOTECHNOLOGIES</th>
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<tr>
<td>Council of Scientific and Industrial Research (CSIR)</td>
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<tr>
<td>Department of Biotechnology (DBT)</td>
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<tr>
<td>Defence Research and Development Organisation (DRDO)</td>
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<tr>
<td>Department of Atomic Energy (DAE)</td>
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<td>Indian Space Research Organisation (ISRO)</td>
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<tr>
<td>Ministry of Communication and Information Technology (MCIT)</td>
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<tr>
<td>Department of Scientific and Industrial Research (DSIR)</td>
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*Table 1: Main government bodies involved in nano-research in India*

*Source: Author*
The ICAR is the national academy of agricultural (including horticulture, fisheries and animal sciences) research management whose directive is to work on agriculture policies. Their mandate is to protect the performance of current technologies in agriculture as well as try and understand, forecast and assess the potential of upcoming and emerging technologies. ICAR has also developed a Five Year 12th Plan document (ICAR 2010), which outlines nanoscience and technology in agriculture and allied sciences as primary areas of focus for development and has constituted a committee to identify and fund projects on nanotechnologies. Of the six different areas identified under this initiative, nanofood and packaging are also recognised. This incorporates a focus on delivery systems, nanocomposite packaging material and applications for different agriculture and allied products. Under this scheme twelve different working research groups have been identified to work collaboratively in specific/identified areas based on their individual Institute’s mandate and competency.

2.4.2 Regulating nanotechnologies in India

Like most other developed and developing countries, India does not have a nano-regulation (TERI 2009b; Sarma 2011). A 2010 TERI report pointed out that nanotechnology-specific legislature is not necessary at this stage of its development in India, because of the unavailability of sufficient information and uncertainty pertaining to nanotechnology risks, but recommended revising the existing regulations as more information on the risks are known. A precautionary principle was also suggested.

In February 2010, the Nano Mission Council announced that a Nanotechnology Regulatory Board will be launched to regulate products of nanotechnologies (Press Trust of India 2010; APCTT-ESCAP 2010), though this has yet to be realised.

Policy measures and support are taken up at various levels and departments within the government. However, the regulation of nanotechnology falls under the onus of DST. Figure 5 provides key institutional actors involved in nanotechnologies.

The Bureau of Indian Standards (BIS), under the aegis of the Ministry of Consumer Affairs, Food and Public Distribution (MCA), is the national standards authority of India equipped with the task of developing standards and certifying products and systems, and is involved in risk assessments of nanotechnologies in India. BIS comprises of two committees, focusing on
nanotechnology (Nanotechnologies Sectional Committee – MTD 33), which liaises with international committees (ISO/TC229/WG2) and the other on medical biotechnology and nanotechnology (MHD21), which deals with (ISO/TC229/WG3) health, safety and environment (EHS) pertaining to nanotechnologies. MTD 33, however, does not have consumer products in its agenda (Ramani et al. 2010, p.9). Representatives from DST, DIT (Department from Information Technology), CSIR research centers, academia and few private firms are involved in the ISO/TC 229 committee (Sharon 2013, p.70).

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**Figure 5: Government agencies involved in nanotechnologies in India**

*Source: Author*
The National Physical Laboratory (NPL) in New Delhi is also involved in the development of standards for nanotechnologies (GoI Annual Report 2013).

While the Ministry of Health and Family Welfare (MoHFW) is responsible for the control and prevention of health-related hazards, they are found to be less involved in the governance of nanotechnologies. Where they are involved, it is only through the Indian Council of Medical Research (ICMR).

Recently, in an attempt to capture nano-based R&D projects the Nano Mission (NM) group initiated a Technology Registry, inviting scientists to register their N&N ventures. However, while the NM website lists eighty six experts on their website under the Experts List category, there are only seven projects listed under Technology Registry\textsuperscript{36}.

India is one of the few nations in the world that has developed a draft guideline detailing ‘Guidelines and Best Practices for Safe Handling of Nanomaterials in Research Laboratories and Industries’ (GoI Annual Report 2013).

Various agencies in India are involved in the risk assessments of nanotechnologies (see Table 2).

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<tr>
<th>AGENCIES INVOLVED IN RISK GOVERNANCE OF NANOTECHNOLOGIES</th>
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<td><strong>Government</strong></td>
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<td>• Ministry of Science and Technology</td>
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<td>• Ministry of Environment and Forest</td>
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<td>• Ministry of Chemicals and Fertilizers</td>
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<td>• Ministry of Labour and Employment</td>
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<td>• Ministry of Consumer Affairs</td>
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<td><strong>Non-government</strong></td>
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<tr>
<td>• Federation of Indian Chambers of Commerce and Industry (FICCI)</td>
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<tr>
<td>• Energy and Resources Institute (TERI)</td>
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*Table 2: Agencies involved in risk governance of nanotechnologies in India*

*Source: Sharon (2013)*

\textsuperscript{36} As of 6 February, 2015.
2.5  Gaps in literature

In reviewing the literature and engaging in the discussions on new and emerging nanotechnologies, several gaps have been noted.

First, as pointed out in the literature review, various national and international debates on the benefits and risks of nanotechnologies are characterised by high degree of uncertainty. Such risks have highlighted the inadequacies in regulation and responsibilities. Yet innovators are increasingly being scrutinised and asked to conduct R&D ‘responsibly’ in order to effectively manage the (potential) risks of nanotechnologies. However, contemporary innovations include the interactions of many actors which complicates issues of responsibility as to who is ‘responsible’ for the governance of nanotechnologies (Bakker et al. 2014). This is presented as a gap in literature, which needs further investigation.

Second, engaging with the views of multiple actors can also be challenging because of considerable variation in their perceptions. This is particularly difficult in the F&FP sectors where actors such as regulators, ethicists, firms and activists (including consumers) have different perceptions on risks, benefits and responsibilities associated with nanoscale particles in F&FP. Considering the polyvalent nature of ‘responsibility’ in nanotechnologies, the concept of ‘responsible innovation’ has been introduced as an approach to manage innovations in such emerging technologies as nanotechnologies. In addressing the importance of responsibility among actors, there are notable absences in the literature on the notions of ‘responsibility’ and/or ‘responsible innovation’ as perceived through the lens of actors in the nanotech F&FP sectors, which this study endeavours to fill.

Third, although there has been a growing literature (and journals) on the ethical issues of nanotechnologies (Kjølberg and Wickson 2007; Viseu and Maguire 2012; Patra et al. 2009; Sweeney et al. 2003) and emergence of the concept of responsible innovation (Pandza and Ellwood 2013; Pavie et al. 2014; von Schomberg 2013), there are few (very sparse) empirical studies that investigate perceptions of a heterogeneous group of actors in the nanotech F&FP sectors through in-depth interviews. A study conducted by Bakker et al. (2014) in the

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37 I use the terms ‘responsibility’ and ‘responsible innovation’ interchangeably in order to connote ‘responsibility’ in innovation’
Netherlands provided perceptions of actors in the nanofood industry, however, it does not focus on notions of ‘responsibility’. A government study conducted by the Toray Research Center in Japan looked at manufacturers’ perceptions of nanotechnologies use in the F&FP and food equipment industries and co-operative associations. However, the research was conducted through a survey and did not provide an in-depth study on the notions of ‘responsibility’ of manufacturers (FSCJ 2010). While, the Nanoplat FP7 Science in Society project involved a deliberative process involving perceptions of a range of actors from within Europe using online chat (CORDIS 2010), these were not focused to the F&FP industry, rather on all consumer products. This study tends to fill these gaps by providing an in-depth study on the perceptions of ‘responsibility’ of a varied group of actors with a focus on F&FP.

Fourth, it can be noted that most of these available studies on perceptions of actors are almost exclusively considered from the perspective of developed/OECD nations, have limited variation of actors in their study, and do not specifically investigate the notion of ‘responsibility’, creating a huge gap in existing literature. Some studies have focused on the perceptions of ethics in scientists in emerging nations like India (Patra et al. 2010; Sahoo 2013), though these do not focus on F&FP. Furthermore, while there has been a sharp increase in literature examining the ‘responsible’ development of nanotechnologies and its socio-economic impacts in developed countries (Seear et al. 2009), India-specific literature on the ‘responsible’ development of nanotechnologies is relatively embryonic with only a few emerging in recent years as compared to those produced in the West. While there are various comparative studies on regulations of nanotechnologies in various countries, comparative perspectives across perceptions of ‘responsibility’ in nanotechnologies are virtually missing from the literature. A comparative study between Europe, China and India examines the ethics debates on nanotechnologies (Fautz et al. 2014) but does not provide reflections on perspectives of actors or focus on F&FP. Another comparative study on the ‘responsible’ development of nanotechnology provides only a snapshot of research programmes in twenty five countries, including South Africa and China, but excludes India and does not focus on F&FP (OECD WPN 2013).

This thesis, therefore, attempts to shift the geographical focus and investigates the notions of ‘responsibility’ in a developing/transitioning country – India – therefore providing an understanding of RI from the perspective of an emerging/developing country, while also
investigating the notions of ‘responsibility’ in a developed country - Canada. More specifically, it contrasts the notions of ‘responsibility’ pertaining to nanotechnologies in developed and developing economies, which provides a benchmark for contrasting notions of ‘responsibility’ between an OECD and a non-OECD economy, currently absent in literature.

Thus, despite the growing questions on who should be ‘responsible’ for the ‘responsible’ governance of nanotechnologies in the F&FP sectors, whether in developed or developing countries, the current literature does not provide empirical studies that specifically focus on the perceptions of RI among actors on a comparative context between developed and developing/transitioning countries in the F&FP, nor does it specifically focus on the dynamics of RI in a developing country. This thesis seeks to help fill these gaps and contribute to the existing literature in the area.

2.6 Conclusions

2.6.1 Summary of this chapter

In the above sections, discussions evolved from risks of nanotechnologies to the emerging notions of RI, which forms the basis of this research. While providing a narrative of nanotechnologies, the discussions indicated that despite the potentials of the technology, nanotechnologies pose new risks which are unknown and strongly contested. The ongoing issues of risks to human health and environmental requires much attention if the potentials of nanotechnologies are to be realised, especially in sectors like F&FP. However, the uncertainty in the (potential) risks of nanomaterials and the absence of sufficient knowledge pertaining to the unique size and physio-chemical properties of nanomaterials, has created regulatory gaps, which hinders the governance of nanotechnologies. Literature shows that existing norms for bulk materials are being applied and it remains contentious whether new regulations/legislations are needed.

Further, with innovation in nanotechnologies growing across continents, the governance of nanotechnologies has become even more challenging, where nano-products are able to penetrate borders without barriers. There are no existing approved protocols to assess the presence of nanomaterials that have the potential to be of risk to human and environment. Specialised instruments are needed to identify nanomaterials in products, which can be
expensive and requires skilled workforce - thus making it harder to govern what products are entering markets, especially at the borders.

These challenges bring forth two major issues within current literature: regulation/governance of nanotechnologies, and ‘responsibility’ of actors. Both these elements are difficult issues because it is unclear whether existing regulatory practices and notions of ‘responsibility’ apply to nanotechnology. In order to understand how key actors in the nano space are dealing with current norms in an environment of uncertainty in regulations and risks, these categories need further investigation.

First, as nanotechnology is being actively pursued in both developed and developing economies (because it has huge appeal to both but for different reasons), it becomes essential to study these economies. An understanding is needed how regulation and ‘responsibility’ are being developed/perceived and applied in these economies with disparate regulatory settings, and what (if any) are the existing norms and practices (hard and soft laws) that are being applied to govern products of F&FP incorporating nanotechnologies.

Second, ‘responsibility’ in food is significant but due to complexity of nanotechnologies and participation of many actors, ‘responsibility’ pertaining to nanotechnologies is vague. Further, without regulation and sufficient risk data, no one acknowledges or wants to acknowledge responsibility. This raises questions of who is ‘responsible’ when it comes to nano F&FP. Hence, there is a need to understand who the actors think is ‘responsible’ and how is ‘responsibility’ understood by them and/or practiced in each region in the absence of specific nano-regulations.

Third, from the literature, we have also learnt that in Canada, the issue of risks of nanotechnologies to human health and environment are a growing priority, while that in India appears to be limited/absent. The literature also demonstrates that in both, Canada and India, there are already a number of nano-based products in the market, which creates further challenges of regulation and ‘responsibility’. Under these circumstances an understanding of how existing legislations are being applied in the F&FP sectors in OECD countries is needed; and whether a similar stance is being taken in a non-OECD country. What are the differences and similarities in existing notions of ‘responsibility’ and regulation in these regions?
2.6.2 Connecting to Chapter 3

From the literature review, it was learnt that with growing questions on who should be responsible for the ‘responsible’ governance of nanotechnologies, the emergent concept of RI has taken precedence in policy debates on nanotechnologies, especially in OECD/developed countries. In the next chapter, I will discuss how over the last few years, the literature on RI has been dominated by various frameworks. I will argue that while these frameworks provide some important aspects on various contexts of innovation (e.g. involvement of stakeholders in the innovation process, meeting the grand challenges, etc.), the frameworks fail to take into perspective the regional context of ‘responsibility’ in innovation and are focused to the Global North. It is therefore necessary to develop a more comprehensive framework, which include the regional context, an essential element of this study, and which can be applied universally. In view of this, in the next chapter I will provide a conceptual proposition through a framework (the R³ Framework for Responsible Innovation) that takes into perspective three factors – responsibility, regulation and spatialty/region - and their inter-relations – responsibility-regulation, regulation-region and region-responsibility – which I believe are essential to the governance of new technologies. It discusses in-depth why these three dimensions are important to the governance of new and emerging technologies like nanotechnologies.
CHAPTER 3

CONCEPTUAL FRAMEWORK AND RESEARCH QUESTIONS: THE R³ FRAMEWORK FOR RESPONSIBLE INNOVATION

3.1 Introduction

3.1.1 Connecting from previous chapter

From the discussions in the literature review in Chapter 2, it was learnt that despite the hype and exponential benefits of nanotechnologies, the perceived risks and the uncertainties surrounding this technology, the absence of regulation and the unique nature/properties/size of nanomaterials, has raised serious concerns of EHS and ELS issues. However, this has not stopped products from proliferating into the market. In addition, the increasing application of nanotechnologies in F&FP has intensified discussions and debates on the risks and regulations of nanotechnologies. With the involvement of a heterogeneous group of actors in the nanotech food chain, there are growing questions and debates as to who is ‘responsible’ for the governance of nanotechnologies.

3.1.2 Aim of this chapter

In order to understand how nanotechnologies emerge under different institutional frameworks and what it means to act ‘responsibly’ across two diverse geographical territories (Canada and India), three factors need to be present and analysed, separately, as well as in their inter-relationships. A review of the literature shows that the emergent concept of RI has taken precedence in policy debates on nanotechnologies, but is limited to OECD/developed countries. Thus, in order to understand how notions of RI and governance play out in different national settings a three-dimensional analytical framework incorporating – region, regulation and responsibility (R³) – is proposed for my thesis. The three dimensions are represented in the

38 Formal laws, regulations, and procedures, and informal conventions, customs, and norms
form of three spheres or themes, which are interrelated (region-regulation, region-responsibility and regulation-responsibility) (See Figure 9), and which together provide a framework for RI for analysing the differences in regulation and ‘responsibility’ in different regions.

In the following sections, I will begin with a brief examination of existing definitions and models of RI and governance frameworks. After a critical review of one of the most used governance framework, the IRGC Risk Governance Framework, I will provide an analysis of the newly proposed R³ Framework for Responsible Innovation. I will then examine each of the three thematic dimensions (and their inter-relations) and investigate them at a more conceptual level. I will take into context regional differences of people’s ‘evaluative relation’ of the world based on the normative notions of what is ‘good’ or what is ‘bad’ and their framings of technology. In doing so, I will also present the research questions that will be used to investigate the notions of ‘responsibility’ through the lens of actors in different national regulatory settings.

3.2 Discussing the categories of the analytical framework

3.2.1 Responsible Innovation

The rise of ‘responsibility’ in innovation and governance

The ‘responsible’ approach to innovation governance has been gaining considerable attention and focus over the years. As briefly discussed in the literature review chapter, concepts of ‘responsibility’, ‘responsibility innovation’ (RI), ‘responsible research and innovation’ (RRI) have been evolving as new approaches for the governance of innovation. While gaining importance in Europe (through the concept of RRI), this new aspect of ‘responsibility’ is also slowly gaining importance among policy-makers, governments and practitioners and are increasingly being institutionalised in public policy debates and practices.

According to Owen et al (2013), the traditional objective of RI was to enhance economic growth, expand profits, and enable competitive advantage, among others. The more recent (newer) concept of RI focuses on addressing societal needs, which keeps in check the future

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39 Developed within the Europe’s Horizon 2020 concept
40 In this thesis, I will use the more universal term Responsible Innovation or RI
implications and consequences of innovation. Therefore, RI is being used to help balance the various socio-economic and environmental aspects in innovation processes.

The ‘responsible’ approach has especially been seen in new and emerging technologies like synthetic biology, information technology and nanotechnology, among others. As a new and complex concept RI aims to link innovation and responsibility. While some believe that RI is a new component of technology governance (Grunwald 2014, p.24), others point out that ‘responsibility’ in innovation has been there through the concepts of corporate social responsibility (CSR), ethics, accountability and sustainability. Thus, the notion of RI is both old and new (Stigoe et al. 2013) that has evolved as technologies have progressed over the years and is expected to continue to change.

RI is only just making its way into science policy debates in the Western world, and yet to be engaged by stakeholders such as policy-makers and researchers (Euroscientist 2014). Moreover, RI hasn’t as yet entered debates when addressing emerging technologies in emerging/transitioning markets. However, reflections of the ideas and concepts of RI in research and innovation of new and emerging technologies can be seen in various similar terminologies and analogies, such as anticipatory governance, responsible development, research integrity, technological assessment (Grunwald 2014b), public engagement, ELSI and ELSA (Tancoigne et al. 2014; Zwart et al. 2014), research ethics, responsible conduct of research (RCR)41, among others. As an evolving concept, RI takes into perspective future scenarios (consequences of which may be good or bad) that are the result of today’s innovation (Ubois 2009). Thus, the aim of RI is to reframe the way R&D in science is carried out by making changes to business and research practices.

The ideas of RI have been reflected in various definitions proposed by experts, academics and government alike. A common denominator in these definitions is the focus on stakeholder participation in RI. For example, the EC RRI definition outlines the need for actors that are involved in R&D to obtain knowledge at an early stage and evaluate societal needs and moral values to develop new products and services. RI is:

41 Widely used in America (Kalichman et al 2013)
“... a comprehensive approach of proceeding in research and innovation that allows stakeholders that are involved in the processes of research and innovation in an early stage (A) to obtain relevant knowledge on the consequences of the outcomes of their actions and on the range of actions open to them and (B) to effectively evaluate both outcomes and opinions in terms of societal needs and moral values and (C) to use these considerations (under A and B) as functional requirements for design and development of new research, products and services.” (European Commission 2013, p.3)

While the EU definition focuses on ethics and orients towards societal needs, “to obtain relevant knowledge on the consequences of the outcomes of their actions” can be highly ambitious, considering the huge scientific uncertainty surrounding such new technologies as nanotechnologies. History has shown that there has been limited progress on this aspect over the past twenty years and remains a challenging issue.

Von Schomberg’s definition of RRI stresses transparency and interactions between actors and innovators to enable innovation and product acceptability:

“Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society).” (von Schomberg 2013; von Schomberg 2012)

While von Schomberg’s definition has been widely accepted by many researchers, specifically in the EU, the same has also generated criticism by researchers in the U.S. (Davis and Laas 2014). Davis and Lass (2013) outlined discrepancies in von Schomberg’s definition, labelling it as “ethnocentric”. According to them, von Schomberg’s definition appears to say that RRI is not required to protect society outside of Europe and also excludes groups (such as those in countries receiving funding) that have an obvious stake in European research. The duo remodelled the definition as follows:

“Responsible Research and Innovation (RRI) is a transparent, interactive process by which researchers, innovators, and other societal actors become mutually responsive
to each other with a view to embedding scientific and technological advances in society in societally desirable ways (including, but not limited to, ways that are sustainable and ethically acceptable)” (Davis and Laas 2014).

In the U.K., The Engineering and Physical Sciences Research Council (EPSRC) frames RRI around similar dimensions describing it as a process that pursues creativity and promotes opportunities for science and innovation that are “socially desirable” and carried out in the interest of the public42.

Owen, Macnaghten, and Stilgoe (2012) developed the ‘anticipation, inclusion, reflection, responsiveness’ framework for their analysis of responsible innovation. According to them:

“RI can be implemented by developing institutional capacities that can help researchers to anticipate the potential future impacts and implications of innovation, which opens up a broader and inclusive dialogue, that encourage reflection on the motivations for and potential implications of the research, and that use these processes to influence the RI process itself in a responsive manner”.

In a later publication, Stilgoe et al. (2013), however, proposed a simpler definition based on the notion of responsibility that emphasised on care for the future:

“Responsible Innovation means taking care of the future through collective stewardship of science and innovation in the present.”

Although interpretively similar, these varied definitions of RI/RRI suggest that even in the developed world there are subtle variations in the perceptions of ‘responsibility’ in innovation and a lack of uniformity in accepted definitions across different geographical domains. Hence, we can assume that in developing countries there may be similar variations and interpretations of what RI is and it cannot be assumed that there will be wide acceptance of definitions of RI proposed by the developed world in developing countries. Thus, it would not be far-fetched to suggest that the perceptions of ‘responsibility’ in the developed world is different from that in developing countries.

42 EPSRC Framework for Responsible Innovation: https://www.epsrc.ac.uk/research/framework/
Frameworks of RI

Over the last 1-2 years, many academics and experts have also attempted to develop frameworks for RI in science and technology (Stigoe et al. 2013; Owen, Stilgoe, et al. 2013; von Schomberg 2012; Owen, Bessant, et al. 2013). There have been various common elements that have been discussed in these frameworks, such as inclusion of stakeholders, ethics and addressing grand challenges.

Von Schomberg (2012) proposed a framework based on values largely derived from EU policies, treaties and documents. Voeten et al. (2013) conceptualised RI as a societal process in a five-stage model, which outlines ‘responsibility’ as a societal process developed through a network of interactions and power relations, learning and includes broader social and environmental aspects. In a more recent report a “meta-regulatory” governance framework was proposed by the ResAGorA (Responsible Research and Innovation in a Distributed Anticipatory Governance Frame) team, which focused on principles and existing initiatives and practices of actors (Randles et al. 2015).

The IRGC Risk Governance Framework (see Figure 6), proposed by Mike Roco and Ortwin Renn in an IRGC report in 2006, is one of the most frequently used governance frameworks. Their model was proposed around a ‘generational’ concept that focused on the global governance of risks which currently cannot be addressed with traditional assessment methodologies, tools and decision-making processes. The framework is based on a careful examination of existing scientific and regulatory uncertainty, identifying and analysing current risk governance deficits, and proposing initial recommendations for decision-makers (e.g. governments and industry) for the management of those deficits.

IRGC Risk Governance Framework

Risk governance is key to ‘responsibility’ in innovation. The International Risk Governance Council (IRGC)43 defines risk as “an uncertain (generally adverse) consequence of an event or an activity with respect to something that humans value”; and governance as “the actions, processes, traditions and institutions by which authority is exercised and decisions are taken and implemented (IRGC 2008; IRGC 2009). Therefore, risk governance pertains to the

43 An independent not-for-profit Foundation based in Geneva, Switzerland
institutional arrangements (e.g. regulatory and legal structures, processes and mechanisms such as markets, incentives or self-imposed norms and standards), that also involves the identification and collection of information, analysis/assessment of the risks, management and communication of risks (IRGC 2005).

IRGC’s approach to risk governance involves five phases - pre-assessment, appraisal, characterisation and evaluation, management, and communication (IRGC 2005; IRGC 2009) (See Figure 7), which can be applied to such emerging technologies as nanotechnologies.

**Phase 1: Pre-assessment**

In this phase, decision-makers are required to outline the scientific characteristics and applications of the technology. This phase also involves researching and identifying any issues that may be raised by various actor groups, such as government, industry, the scientific community, NGOs and the general public.

![Figure 6: The IRGC Risk Governance Framework](image)

*Source: IRGC (2009, p.13)*
Renn and Roco (2006, p.156) predicted an evolution of four overlapping generations of nanotechnology products and processes, which, according to them, has the potential to evolve over a twenty year period, between 2000-2020 (see Figure 8) - from passive nanosystems and nanostructures which exhibit simple/stable behaviour and are already in the market or will shortly be in the market and therefore requires immediate action (referred to as Frame 1); to active (evolving function) complex nanosystems and nanostructures in the long-term that are less predictable by scientific analysis and are transformative (referred to as Frame 2). Frame 2 requires higher levels of knowledge and capacity to control the nanostructures and for rigorous assessments. According to the authors, each of these frames extend a different set of risk governance concerns (though some may also be common to both) that will need to be addressed. The applications of nanotechnologies in food and food packaging fall under Frame 1 (IRGC 2009, p.15) as these high risk nano-products have high production scale and exposure.
Phase 2: Risk Appraisal

Once the risk is identified in the pre-assessment stage, phase 2 reviews whether a risk should be taken and if so, how it can be managed, reduced or controlled. This involves two phases: (i) a risk assessment phase where there is a scientific assessment of the risk and the probability of the risk occurring; and (ii) a concern assessment phase which involves stakeholder concerns and perceptions of risk. The implication of the risks in terms of not only its direct consequences but also potential societal reaction should also be considered by risk managers (Renn and Walker 2008). Thus, the risk appraisal phase includes gathering information through science-based assessment of the risks to human health and environment (involving natural and technical scientists) as well as social and economic implications of the risks to society (collected by economists and social scientists). In gathering all the information risk managers are then able to make informed decisions and implement appropriate risk management strategies.

The risk assessment element of the framework is primarily important for Frame 1 nanostructures where the speed at which products are developed and applied largely exceeds
the ability of risk evaluators to assess any new risks concerned with the product (IRGC 2007). Furthermore, the absence of sufficient publicly-available data can lead to misinterpretation of information in the media and from NGOs.

On the other hand, the concern assessment element of the framework is primarily important for Frame 2 where there is limited knowledge of risks and actors are more concerned about the social acceptability and desirability of the innovative product.

**Phase 3: Tolerability and Acceptability**

This phase focuses on characterising the various states of knowledge in Frame 1 and 2 and endeavours to evaluate the extent of risk based on acceptability and/or tolerability of society.

Renn and Walker (2008) have suggested that a risk is ‘tolerable’ when an activity is worth carrying out due to the benefits that it may have but would require further efforts in reducing the risks “within reasonable limits” (p.28). The term ‘acceptable’, on the other hand, refers to an activity where the risks that remain are so low that further effort is not seen as necessary in reducing the risk. According to them judgements on acceptability depend on two aspects – *values* and *evidence* (p.29). While evidence alone cannot lead society to tolerate or accept something, it is still important in order to understand if a certain value has been violated and to what degree. They distinguished three cases – (i) *interpretative ambiguity* which entails ambiguity on evidence but not values. Here risk is interpreted by the uncertainty associated with the probability of the event occurring (such as an earthquake) and the magnitude of losses (such as monetary losses to homes after the earthquake); (ii) *normative ambiguity* which entails ambiguity on values but not on evidence. Here values that are tolerable or acceptable may be disputed where evidence may be provided and non-controversial. The judgement is based on discourses pertaining to the values. For example, despite the evidence of the harm that smoking may cause, some countries leave consumers to make their own decisions while others initiate major activities such as a ban on advertisements and displays to curtail smoking; (iii) *Interpretative and normative ambiguity* where there are ambiguities on values and evidence. In this case both the evidence and the values are disputed. For example, the uncertainty and complexity of global climate change due to greenhouse effects leads to values-based decisions by governments on whether to prevent or mitigate. The process of judging the societal tolerability and acceptability of risk can be carried out through *risk characterisation* and *risk evaluation*. 
While risk characterisation is carried out based on results from scientific evidence from the risk appraisal phase, risk evaluation involves broader value-based issues such as technology choice, societal needs and balancing of risks versus benefits, policy-making, besides others.

**Phase 4: Risk Management**

The aim of the risk management phase is to develop strategies that can help prevent, reduce, transfer or retain risks. Risk management is essential for both Frame 1 and Frame 2. In Frame 1 much of this can be achieved through current regulatory structures and processes, however, in Frame 2 risk assessment methodologies may not exist and thus will fall outside the remit of regulatory processes. This phase allows risk evaluators in decision-making on risks for each frame, while taking into account the views and requirements of actors.

While the government is the “formal authority” in a State, “with legislative, policy making and executive powers”, governance encompasses other stakeholders than just formal government bodies (Malsch and Nielsen 2009). The scope of responsibilities and accountability and the transboundary nature of nanotechnologies make it essential that governments, businesses, the scientific community and civil society actors co-operate on identifying and managing the risks associated with nanotechnology (Renn and Roco 2006, p.12). Various actors perceive risks differently (IRGC 2005, p.32), hence it is essential to incorporate these actors’ perspectives when addressing risks.

**Phase 5: Communication**

Once decisions on management of risks are provided, the rationality of the decisions made would need to be communicated to the various stakeholders who are involved in the risk governance process. This will allow individual actors to make their own informed decisions/judgements on the severity of the risk, their role in managing this risk and their individual responsibility in curtailing any unprecedented mishap. Communication is the backbone of risk governance that allows actors and stakeholders to understand risks and their role in risk governance, as well as allowing them to contribute to the debate on risk concerns of nanotechnologies (Renn 2008). It also helps to build trust through the process of risk governance. Risk communication needs to involve the active participation of risk assessors, risk managers in public and private institutions, risk regulators, policy-makers, legal as well as technical and social scientific entities to enable risk governance and management.
Limitations of IRGC Risk Governance Framework

The literature suggests that the (potential) risks and uncertainty from nanotechnology constitute new and emerging issues. This generates huge challenges in the development and governance of nanotechnologies due to various mitigating reasons ranging from scientific gaps due to its small size and diverse properties to ethical concerns and regulatory gaps. These risks have major international implications with the potential to harm human and environment health and safety. Yet, the societal importance of nanotechnology applications cannot be discounted. In order to reap these societal benefits, enhance economic growth, ensure public health and safety, protect the environment, as well as support international collaborations and progress, the risk governance of nanotechnology is essential (Roco et al. 2011, p.3557).

While the IRGC risk governance framework’s focus is on risk appraisal, assessment and management, it can be pointed out that such policy briefs often incorporate Western inputs. For example, the policy brief on the appropriate risk governance strategies for nanotechnology applications in food (and cosmetics) was a result of the workshop organised by IRGC in Geneva in 2008 which included the participation of (thirty six) experts from the Western world – such as Canada, the United States (US), Korea, Japan and various European countries (IRGC 2009) - and lacked the participation of actors from developing (and emerging) countries. The IRGC report argues that the framework is unique because it distinguishes between risk problems that are “simple, complex, uncertain and ambiguous”; encourages the early and active participation of all stakeholders, including civil society, industry and regulators, in risk debates, integrating their opinions, values, and roles into the governance process, and; incorporates the principles of ‘good governance’, which comprises transparency, accountability, sustainability, equity, fairness and ‘respect for the rule of law’ (IRGC 2005, p.52).

However, in a world of globalisation, R&D processes and products of innovation are continuously being shared between developed and developing countries through the participation of networks of actors involved in the innovation processes. This creates significant and demanding challenges for the governance of new technologies. Furthermore, public debates on new and emergent technologies often focus on ‘responsibility’ and regulation

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44 According to Knight (1921), uncertainty refers to something that is non-existent (unmeasurable) and has neither outcome nor probability (commonly referred to as Knightian uncertainty), and risk as “measurable uncertainty” or “risk’ proper” where one can assign probabilities to outcomes (measurable).
- who is responsible for governance of these new technologies, and what are the regulatory mechanisms that govern these technologies?

While the IRGC risk governance framework and other frameworks focus on important elements of RI such as awareness of broader social and environmental issues, early discussions and participation of actors on issues and varied forms of ‘principlism’ and practices of ‘responsibility’ among actors, these frameworks fail to take into perspective the regional context of ‘responsibility’ and regulation in innovation. Most of these frameworks appear to be largely designed for Europe, U.S. or U.K. (the global North), though it is argued that it has “more general application and relevance” (Stilgoe et al. 2013, p.1568). This “neo-colonilization” of RI (Macnaghten et al. 2014) thus identifies a severe gap in a framework that can be used across different national contexts, which will be addressed in this thesis.

Because the new concept of RI is still evolving, the social and ethical implications of innovation processes on a regional context is still under-researched and under-developed. While the IRGC framework does outline the core risk governance process, and recognises the importance of inclusion of various organisations and actors during its implementation, the model implicitly assumes that it can be applied across different regional domains and therefore fails to take into perspective the perceptions of ‘responsibility’ of actors across trans-economic boundaries with differing social and regulatory settings. The framework does briefly attempt to address the issues of risk governance on a transboundary level by recommending the inclusion of developing countries at an early stage of dialogues and communicating international standards and best practices to both developing and developed countries in a timely manner. In so doing, it implicitly places developing countries on a similar basis as developed countries without recognising the structural, cultural and socio-economic constraints that characterise them. This warrants a more comprehensive reassessment of the implication of countries with diverse regulatory settings and varied values.

I therefore propose an alternative framework that brings to the fore the notions of ‘responsibility’ and regulation on a regional context. For the purpose of this study, I have used the more general term ‘responsible innovation’ (RI) as the focus for my framework and research.
Analytical framework to analyse the governance of nanotechnologies through interfaces of responsibility, regulation, and region

Figure 9: The R³ Framework for Responsible Innovation

Source: Author

In order to answer the question of who is responsible for the (risk) governance of new and emergent technologies like nanotechnologies, there is a need to understand the notions of ‘responsibility’ of a multiple and heterogeneous group of actors that participate in the innovation process. As the perception of ‘responsibility’ may differ in different geographical settings (based on different cultural settings, values and ethical standings), it is essential to take into perspective notions of ‘responsibility’ in different regional settings. What are the perceptions of ‘responsibility’ of actors within these regions and how do they differ, if they do? It is also necessary to examine how their notions of ‘responsibility’ are framed based on their normative understanding of new and emergent technology within these different regional/institutional settings. In this respect, it is necessary to analyse the institutional settings of these regions in order to investigate how ‘responsibility’ is influenced and practiced within these regions through institutional mechanisms that may incorporate hard or soft laws. By
examining ‘responsibility’ and regulation on a regional context, it will further help gain an understanding of how the two essential elements affect different geographies and markets of new and emergent technologies. Further it has been acknowledgement in literature that the risks of nanotechnology can be widespread - across different boundaries and economic groups (Renn and Roco 2006, p.15). Therefore, I argue that the inclusion of region is an important and essential component of the RI framework where the notions of ‘responsibility’ of actors, and the differences in institutional structures are also present. In order to explore how these three elements are essential to the governance of new (nano)technologies I propose an alternative framework that brings to the fore the issue of governance on a trans-boundary and trans-economic level.

In the following sections, I present a three-dimensional analytical framework and discuss its three dimensions – region, regulation and responsibility (R3) – separately, as well as in their interrelations – region-regulation, region-responsibility and regulation-responsibility.

3.2.1.1 Region

Innovation in OECD and non-OECD countries

In recent years, globalisation has facilitated extensive competition through trade liberalisation and foreign trade investments in both OECD and non-OECD countries. Globalisation, while increasing competition, has also intensified the drive to create technological innovations, a key component of competitiveness, development and growth of nations, regions and firms. In order to stay abreast in this highly competitive environment, countries and organisations are becoming more specialised through technology-intensive innovations that have created opportunities for new markets. Over the decades technological innovations in new and emerging technologies (such as information technology, biotechnology, genetic engineering) have undergone a rapid transformation and has become a major part of development agendas, especially in industrialised economies (Marton and Singh 1992, p.133). This growth in technological innovation is no longer restricted to OECD countries but also involves non-OECD countries. Inadequate technological absorption can result in significant competitive disadvantage. Thus, in order to avail the potentials of new technologies, a new emphasis on technological development and policy changes are being made in developing economies and emerging BRICS nations. It is expected that the most significant long-term impacts of new
technologies are likely to be faced by these developing/transitioning countries due to their ability to compete in global competitive markets. However, Forloni (2012) has pointed out that technology is often controlled by Western countries and multi-national organisations that have patents and licenses (p.11). According to him much of the funding received for research is utilized to support corporate interests and to improve quality of life in developed countries. However, there has also been much attention given to the need for countries in the global South to engage in new technological innovations for socio-economic development.

Nevertheless, emerging technologies present both challenges and opportunities for developed and developing countries. While some technological innovations are easily embedded in society (e.g. information technology which has large and direct benefit to consumers), others fail to thrive (e.g. GMO where there are only few benefits to consumers and higher benefits for producers) due to various reasons - technical deficiency, health and environment safety concerns (potential or real), or a lack of technology pull. On occasions, these efficacies are overcome and there is greater acceptability of the technology.

Furthermore, with globalisation, institutional and national boundaries are no more a hindrance in creating new innovation environments. Innovative products and processes can be moved from one country to another across porous borders through international trade links and research collaborations. These movements may be between developed and developing countries, where governance and regulation may differ.

Thus, globalisation has created undue challenges for the governance of new technologies due to the free movement of goods from one region/country to another. With its various social and ethical issues, it becomes necessary to understand how new technologies are developed in both developed and developing regions. It thus becomes imperative to investigate the two cases of my study, Canada and India. By concentrating on these countries, it becomes possible to examine the differences and similarities in institutional and cultural structures within separate economies. The primary objective is to understand the notions of ‘responsibility’ within each region and contrast these separate understandings to gain a better understanding of responsible innovation at a regional level where there are disparate regulatory settings. Therefore, I am interested in understanding what are the strategies for developing nanotechnologies in the F&FP in these regions and what are the conditions under which these are developed?
3.2.1.2 Regulation

Regulation and institutional structures

Regulation has been described as “controlling human or societal behaviour by rules and restrictions” (Koops et al 2006). Unlike governance, which involves both private and public actors, the State is the only primary and legal entity with a right to regulate (TERI 2009b, p.7). Regulations are primarily established for the benefit of the consumers and public at large (Stigler 1971), as well as for industry to encourage economic and social goals (Smith 2000). These may include hard regulations involving prohibitions, or soft regulations, which are incentive-based (Black 2001). The State can thus be either a resource or a threat to industry (Stigler 1971, p.3) when it comes to regulation of new innovations. The State may either thrust regulation on industry or the industry may seek it (Stigler 1971, p.3). Over the past decade, there has been substantial rise in the formation of new regulations as citizens in many countries demand regulations in relation to health, safety and the environment (Guasch and Hahn 1997). However, if regulation becomes a hindrance for innovation, there is pressure on the government by firms for reforms in regulation. Where it involves new innovations and/or technologies, firms may thus push for reduced regulations (Guasch and Hahn 1997, p.4). Under such circumstances, regulators can often be subjected to a ‘regulatory capture’, where they can be biased towards a particular interest group such as firms, manufacturers and producers in order to stimulate innovation, or be influenced by them (Stigler 1971). This aspect highlights the ability of firms in influencing public policy (Shaffer 1995).

Edquist (2008) has highlighted the importance of institutions in the innovations systems theory. The economic success of a country depends on the institutional structure of the economy (Rodrik 2000), which may comprise of formal constraints (e.g. rules, laws) and informal constraints (e.g. norms of behaviour, customs) (Kirkpatrick and Parker 2004). These institutional structures are deeply embedded in society and play a major role in the way people interact with each other and use their knowledge (Johnson 1992). They are also vital to building trust in society and investments in innovations (North 1990).

The quality of the institutional structures setting has significant effect on the economic growth of a country (Jalilian et al 2003); the better the quality of State regulation, greater the economic growth of a nation (Jalilian et al. 2007).
However, the globalisation of innovation has created more challenges of regulation of novel and emerging technologies (like nanotechnologies and GMO). In the absence of policies and under uncertain risk environments, regulation involving ‘hard’ (legal authority) and ‘soft’ (not legally binding) regulatory approaches through legislation, codes of conduct, standards and voluntary/mandatory reporting approaches, have been created over the years. It is essential to take into perspective the unpredictability of (new) innovation when it comes to governance and ‘responsible’ research and innovation of new technologies (Owen 2012). Despite many market studies carried out by innovators and companies prior to the launch of new and innovative products, the uncertainty in innovation makes it impossible to predict the success (or failure) of an innovative product (Pavie et al. 2014, p.2) by any actor in the innovation chain. This unpredictability in innovation often leads to a weakness in regulation, where it is difficult to establish regulations when the impacts of the innovation are unknown, especially during the initial stages of innovation (Collingridge 1980). Thus, though regulation is important, it has limited powers as a governance mechanism unless impacts of innovation are known (Owen 2012, p.4).

Moreover, in order to establish efficient regulations, the State needs information from those using new innovation and technologies. However, it can be a formidable task to obtain information from innovators if these innovations are not being carried out in State-owned facilities (e.g. by State-led research institutes) as there can be an unwillingness by companies (e.g. private firms, MNCs) to divulge information which may be deemed as intellectual property. Thus, regulation is often linked with information asymmetries where the regulated (e.g. firms) has the information that the regulator needs in order to be able to regulate “optimally” so as to be able to build on social welfare (Kirkpatrick and Parker 2004; Jalilian et al. 2007). Such information asymmetries can further contribute to inadequate regulation (Jalilian et al. 2007, p.88) and regulators face ongoing difficulties that arise due to the absence of information (Parker 2002; Newbery 1999). It is thus essential for regulators to establish specific mechanisms, such as rules and incentives, which can “coax” the regulated to freely impart information (Kirkpatrick and Parker 2004; Jalilian et al. 2007).

It is essential to study the regulatory structure and institutions of a regime in order to ascertain the rate and trajectory direction of innovation. Before being implemented all new innovation and technologies need to cross various technological, societal and regulatory hurdles (D'Silva
et al. 2012) that can mitigate its success, especially if innovation pertains to a sensitive area like food. In the absence of regulations pertaining to new and emerging technologies, I am interested in understanding what are the existing governance mechanisms by which regions with disparate regulatory settings operate and how are these enabling (or conflicting) with innovation in nanotechnologies?

3.2.1.3 Responsibility

Responsibility is a vague and multivalent term and has received far less attention than risks (McCarthy and Kelty 2010, p.408) when it comes to science and technological innovations such as nanotechnologies. The term ‘responsibility’ has been used in various forms and concepts, whether discussing responsibility of multinational corporates, the environment, or novel technologies, for example as in ‘collective responsibility’, ‘Responsible Care®’, ‘corporate social responsibility (CSR)’ or the more recent ‘responsible innovation’. McCarthy and Kelty (2010) have suggested that where risks and risks analysis have failed the new concepts and practices of ‘responsibility’ have emerged (p.406). Thus, ‘responsibility’ is considered to be a complement of risk; where risk is present, responsibility is prominent (McCarthy and Kelty 2010, p.407).

Before further discussing the concept of ‘responsibility’ it is important to distinguish between ‘responsibility’ and ‘irresponsibility’. While measuring risks allows individuals and organisations to make ‘responsible’ decisions and choices, taking unnecessary risks can be seen as ‘irresponsible’; and not carrying out adequate and proper risk assessments can lead to catastrophes and ‘responsibility’ for subsequent detrimental consequences of innovation (McCarthy and Kelty 2010, p.407). Some groups have suggested irresponsible innovation as having a negative impact when the actual intention was supposed to be positive to environment and society (Sutcliffe 2011, p.15). While the consequences of technological innovation cannot be foretold, it is essential to invoke responsible behaviour into what German sociologist, Ulrich Beck45 calls “a system of organized irresponsibility” - where despite scientists and industry being involved in R&D of new technologies, society is unable to hold anyone responsible for the consequences created through modernity. Irresponsibility, thus, may not be an individual

aspect but part of a system where there are many actors involved in the innovation process (Owen, Bessant, et al. 2013, p.30).

Von Schomberg (2013, p.14), on the other hand, suggests that there are four types of irresponsible innovation, taking into perspective various past cases that showed various forms of irresponsibility by the actors involved in the innovation process: (i) technology push - where technologies like GMO were pushed into the market by such companies like Monsanto which resulted in NGO backlash and stricter regulations of GMOs in the EU. This irresponsible action subsequently affected the sector; (ii) neglect of essential ethical principles - In 2011, the Dutch government’s abandonment of an electronic patient record system (EPRS) project due to unresolved privacy issues led to a €300 million loss invested over a fifteen-year period. This unnecessary loss of public money could have been avoided and the project could have been successful had there been an inclusion of stakeholders and public engagement at an early stage of the project to incorporate their inputs on privacy issues; (iii) policy pull - The introduction and use of body scanners at airports in Europe has been controversial as it was found to have limited benefits - it had no mandatory use for passengers, it could not make pictures but only formed representations of the body, and the representations could not be stored. The irresponsibility in this case was in not anticipating these requirements earlier through appropriate technology assessments and public dialogues; and (iv) lack of precautionary measures and technology foresight – lessons from past cases of innovation gone wrong (e.g. asbestos) provides “late lessons from early warnings” (European Environmental Agency 2001). The examples from past cases point to irresponsibility on the part of corporations as well as government. The use of precautionary measures could have curtailed many mishaps and delay in action by the government.

Andrew Maynard relates irresponsibility to over-interpretation of data and cautions how research is interpreted by the scientific community to the media, consumers and government (Maynard 2014). Taking the example of a study carried out by researchers to indicate the potential toxicity associated with fumed silica in food products which is currently considered safe, he points out that it would be irresponsible to “muddle” exploratory data with actionable data without carrying out sufficient research, just because the material falls under engineered nanoparticles. According to Maynard, such interpretations can lead to unwarranted doubts and concerns, which in turn could lead to poor conceptions and decisions on the technology.
Thus, as with the concept of responsibility, the ideas around irresponsibility is vague and diverse when it comes to innovation. The emergent nature of irresponsibility is often a result of uncertainty, complexity and distance, both spatial and time-based (Owen, Stilgoe, et al. 2013, p.33). Governing such an ecosystem is argued as being “almost impossible” and calls for a new way of thinking about responsibility.

However, it is difficult to clarify what “responsible” means and what distinguishes “responsible” from “irresponsible” or “less responsible” innovation”. It has been pointed out that the difference will depend on specific contexts such as values, rules, customs, ethical principles, etc. and there will be similar challenges in implementing ‘responsibility’ (Grunwald 2014b) as that seen in applications of the Precautionary Principle (von Schomberg 2006).

However, as there is growing acceptance that new technologies have the ability to benefit as well as harm society, the debates around ‘responsibility’ has grown (Jonas 1984). This reliance on technological innovations places on members living in this modern technological society, a huge responsibility for the future generations (Jonas 1984, p.40). Responsibility, to some extent, depends on the future consequences of the innovation. “Prediction of the future is needed to act in the present” and in the absence of a reliable prediction of the future, there is a break down in responsibility (Funtowicz and Strand 2011). However, if the consequences of current actions are unknown, how can one know what effects one’s actions would have in future? Since the future impacts of technology (especially novel technologies) are hard to predict (Roco et al. 2011; von Schomberg 2013), Hans Jonas was perhaps the first to consider the concept of the ‘precautionary principle’ when his philosophy of ‘responsibility’ emphasised on the principle that “the prophecy of doom is to be given greater heed than the prophecy of bliss” (Jonas 1984, p.31). Hans Jonas stressed on “visualising the future” and imagining the different outcomes and uses of new technologies (Jonas 1984, p.7).

In terms of novel technologies, like nanotechnologies, ‘responsibility’ may include the protection of science from negative public perceptions, public backlash and de-funding where there is a danger to stall innovation, as well as ‘social’ responsibility which focuses on protecting public health and environment through scientific R&D (McCarthy and Kelty 2010, p.408).

The idea of ‘responsibility’ can be interpreted through different aspects and is often also associated to the terms: (i) accountable (Funtowicz and Strand 2011, p.996) where one is
‘answerable’ or accountable for their actions and expected to own up, justify or give an account of their action (Kaler 2002, p. 328). This may be voluntary or imposed on them by law or society; (ii) liable - There can be two dimensions to responsibility (Kaler 2002, p. 327-328); one that is focused on duty and obligation, and the other that is causal. Responsibility in terms of law would relate to norms and rules. The latter, causal aspect, can result in ‘good’ or ‘bad’ outcomes, making the particular individual/s responsible for success or failure, respectively. If there are negative repercussions of one’s action then the perpetrator has the legal duty to compensate the victim; (iii) responsible – which comes from the word ‘responder’ (to take the oath) where it involves moral commitment, duty and authority of the individual (Pavie et al. 2014, p.8), or from the Latin word, respondere⁴⁶, meaning “to account for decisions” or “to respond” (Zullo 2014; Pellizzoni 2004) to someone or oneself for their actions as well as any consequences that have evolved from their actions (Buzás and Lukovics 2014). To call somebody “responsible” usually means something good about their character, reputation or intentions (Vincent et al. 2011). Being responsible also implies “being able to have rational confidence in one’s own judgment” where others inputs are also needed to develop these capacities for independent practical reasoning, and to help evaluate, modify or reject any judgements (Waelbers 2011). This inclusion of others allows oneself not only to be accountable for the endorsements on the decisions made but also the practical conclusions of others; and (iv) moral – Responsibility also has moral and ethical dimensions to it, where the notions of responsibility is often associated with ethics, morality or moral standards and respect and awareness of one’s actions. Moral standards have normative understandings of what is ‘good’ or what is ‘bad’ (Pavie et al. 2014, p.12) and therefore there is a moral obligation to behave appropriately or correctly. Similarly, the ethics of science and technology engineering are often linked to what is ‘good’ and ‘right’ and what is the right thing to do (Funtowicz and Strand 2011, p.995). Where the nature and consequences of certain actions are known and well-understood, ‘responsibility’ is clear. However, development of novel technologies can give rise to various ethical dilemmas, which can result in “value conflicts” (Funtowicz and Strand 2011, p.995). Hans Jonas talks of the “ethics of the future” where what is to be feared has not as yet occurred. According to him, human actions which expands across borders and geographies

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⁴⁶ used at juridical level (Pellizzoni 2004)
needs to be considered and the long-term effects (ethics) of technological innovations needs to be visualised (Jonas 1984, p.27).

While discussing ‘responsibility’ in innovations, it is also important to distinguish between collective and individual responsibility. Discussions of responsibility in science often tend to focus on individuals (Owen, Bessant, et al. 2013a, p.1). In moral or ethical philosophy, individual responsibility is richly debated around accountability of individual actions (McCarthy and Kelty 2010, p.408). However, as innovation systems are globalised and complex and involve many actors and changes in norms in society, instead of individual responsibility it is essential to think in terms of a collective responsibility (Bakker et al. 2014, p.294). Further, modern “Frankensteins” or unintended negative consequences of innovation are often not intentionally generated by a single individual or actor, but, is often the unforeseen “side effects” of the collective action of a group of actors (von Schomberg 2013, p.13). Whether these impacts are intentional or not, collective responsibility is for both, the good impacts as well as the negative consequences.

The differences and ambiguities of ‘responsibility’ in different languages and cultures has been discussed by various authors, where its meaning in say the French language can be quite different to that in Dutch\(^{47}\). Such differences can lead to misinterpretations of the concept of ‘responsibility’ in people of different nationalities despite the words being the same (Pavie et al. 2014, p.35). Personal values and standards of morality may also differ in the Western world from that of its Southern counterparts.

Thus, the concepts and definitions of responsibility are vast and varied and it would be impossible to discuss all the concepts in this thesis. While there is vast literature on risk perceptions and attitudes of new technologies, there has been little attempt to empirically specify the diverse perceptions of ‘responsibility’ pertaining to new and emerging technological innovations such as nanotechnologies. I argue that such alternative and diverse notions of ‘responsibility’ calls for a deeper investigation in the concept of ‘responsibility’ under uncertainty and what it means to be ‘responsible’ taking into perspective the regional context.

\(^{47}\) See (Pavie et al. 2014)
Role of actors in the responsible development of innovation

Technological innovations can significantly contribute to addressing the grand challenges of society. However, these innovations, while providing solutions to societal challenges can also create unwanted hazards and consequences. It is therefore essential to consider the social and ethical implications of innovation, which can lead to “socially acceptable” and “socially desirable” innovations (Owen, Bessant, et al. 2013, p.167). This is achieved by involving multiple, mutually-responsive actors (see Figure 10) at an early stage of innovation (von Schomberg 2013, p.63).

Von Schomberg (2013) points out that until recently, the control and use of certain technical inventions which has the potential to be harmful (e.g. nuclear weapons), were entrusted to ‘responsible’ entities (such as the military and governments) while others were expected to keep “moral constraint” in order to avoid misuse and negative consequences (p.53). This aspect of “control of consequences” is still dominant in science and technology today (Funtowicz and Strand 2011, p.997). In present innovations while various other industrial innovators have been allowed to make enhancements in innovations (e.g. cars, medicine, airplanes) they are still liable to ensure the efficacy, quality and safety of products and processes through demands by the State. Thus, ‘responsibility’ is administrated through various laws and legislations set by State regulators (von Schomberg 2013, p.4). However, due to a decline in trust in the State, there has been a shift from government to governance, where a heterogeneous group of actors are continually being included into decision-making processes on policy and innovation (Beumer and Bhattacharya 2013).

The participation of societal actors is important to the process of governance of innovation. Responsibility, as an emerging issue, affects various actors involved in science and innovation (Grunwald 2014a). The ‘responsibility’ approach allows various societal actors (researchers, citizens, public sector organisations, policy-makers/regulators, private companies/businesses, CSOs/NGOs, etc.) to work together during the entire research and innovation process in order “to better align both the process and its outcomes with the values, needs and expectations of… society” (European Commission 2014).
There are various roles and responsibilities of actors in the innovation process. Traditionally, ethical thinking was based on the idea of attributing responsibility to an autonomous individual (von Schomberg 2013). However, von Schomberg (2007) argues that in increasing number of instances it is impossible, “even in hierarchically structured technical professional systems”, to assign a single person responsibility for solving some specific issue (p.9). Thus, a shared responsibility is seen as a starting point in research and responsible innovation.

Under the “Westphalian system”48 the State was the only actor that had the responsibility in governing products of innovation (Kobrin 2009). However, due to globalisation a hybrid regime has emerged where there is a shift from a state-centric to a sovereignty-free multi-actor regime. This has led to the fragmentation of public power and various state and non-state actors, such as governments, international organisations, CSOs//NGOs and powerful private firms that are involved in establishing principles, norms and rules in an emergence of mixed regimes (Risse 2004). These actors operate in parallel and are both “sovereignty bound and sovereignty free” (Rosenau 1992) and are legitimately involved in policy and decision-making exercises that was traditionally the responsibility of public authorities (Cutler 1999). While, the three main actors in the innovation system are public and private R&D institutions, government agencies and private firms (Edquist 2001), the role of the State in directing and establishing long-term policies for industry and the economy has been has been emphasised many researchers. As innovation governance involves the inclusion of broader debates and public concerns, legitimate governance of new and emerging technologies thus cannot be achieved by regulators alone.

The role of scientists is equally important. Various past controversies on novel technologies reflect that negotiation of responsibility between scientist and society is an important issue (von Schomberg 2014). Due to the ability of science to influence society, and vice versa, it is important how scientists resolve some of the issues (Rasmussen and Ebbesen 2014, p.1066). In relation to food, the Institute of Food Science and Technology in the UK, point out that the primary responsibility of ensuring safety of products rests on the scientists and technologists, and not just regulators49. Thus, scientists too have a responsibility and role in the governance of innovation and must take responsibility for the ethical dilemmas as a consequence of their

48 A concept that all states have sole sovereignty over their territory with no participation of other entities
49 IFST Information Statement on Nanotechnology: http://www.ifst.org/knowledge-centre/information-statements/nanotechnology
research, and reflect on the social role of their profession. According to Rasmussen and Ebbesen (2014), scientists have the ability to utilize their “ethical competence” to analyse a particular situation using various theories and principles of ethics and make moral decisions on best solutions to carry out research in a responsible way (p.1074). Pavie et al (2014) further emphasise that innovators are the main promoters of responsibility as they have the power to incorporate a responsible element into their projects (p.8). However, no innovator wants to be irresponsible, and while there may be good intentions on the part of innovators, it may result in unintentional negative outcomes in innovation trajectories (Owen 2012, p.5). While new technological solutions do have the potential to change the livelihood of people positively, from the perspective of historical events we know that any new technology can have detrimental consequences, which are unknown when first implemented. Moreover, the entities that are most affected are the ones using the technologies. Some use of potentially beneficial technologies can result in harming innocent victims, whether directly or indirectly. Examples include Chernobyl (nuclear technology) and suicide of farmers in India (GM). Hence, moral concern should always be towards the victims of technological change (Simate et al. 2013, p.185). Humanists, those that are trying to develop solutions for the betterment of society, fail to see a moral issue involved in these new technologies and therefore need to be aware of the moral implications of new technologies when making decisions (Simate et al. 2013, p.186).

It is also important to study the role of corporations and their responsibility as they have become the most powerful institutions and have a major role in societal progress (Goodstein and Wicks 2007). There can be drastic consequences for the company and new technologies alike if even one of the corporations avoided their responsibility in the innovation process (Owen 2012). Within a firm, responsibility can be situated in the accountability of individual actors that are interlinked; towards society at large; in the interactions with its partners such as suppliers; and their awareness of responsibility towards future generations (Pavie et al. 2014, p.14). This final form of corporate responsibility is based on existing knowledge without knowing the impacts of the technological innovation. Of greater relevance are the small and medium sized enterprises with limited resources. It is of paramount importance that these organisations are especially ‘educated’ on RI as they play an essential role in the innovation process.

Also significant are the trans-national/multi-national corporations (TNCs/MNCs). In the wake of increasing integration of the global economy, influential actors, such as transnational
corporations have substantial political power and authority in the international political system (Kobrin 2009, p.3). The traditional notion that States and State agents are responsible for violations and the only entity with “international legal personality” are now being challenged due to the advancement of these powerful actors (Ruggie 2004). Importantly, these private actors exercise power that is perceived and accepted as legitimate. They are continually engaged in authoritative decision-making processes in areas of governance that was previously the role of sovereign states (Clougherty and Grajek 2008) and therefore held liable for violations and imposed with high responsibility in terms of their actions. In many developing countries these large corporations are now taking responsibilities that were historically the responsibility of international development agencies or States (Vogel 2006).

Multinationals are also important actors in the globalisation of innovation. They are actively involved in technological alliances that may entail firms or research institutes. Such alliances not only involve sharing of costs and knowledge, where the new technology is complex and requires intensive knowledge and technical know-how (not otherwise available internally), but that of sharing risks too (Baumol 1992). However, in such alliances, MNCs often maintain a dominant power and ownership over the technology (Archibugi and Iammarino 1999). There are many factors to look at in terms of these transnational corporations moving to a domain different from their own - the profit motive, the political favours, lower standards when evaluating risks, the speed at which commercialisation takes place, the competition, absenteeism of a regulation, ownership of a foreign entity giving rise to intellectual properties, etc. Governments are unable, or even unwilling to regulate firms operating outside their own jurisdiction (Campbell 2006). Legally and politically, these firms fall under the laws of different states where they operate (Kinley and Tadaki 2004) and are under the laws, regulations and established administrative protocols and practices of the country in which they operate. There are concerns from researchers that by imposing direct obligations and responsibilities on private corporations, it would risk relieving the state and “disempowering” them of their responsibilities and duties (Vazquez 2005). However, as firms/TNCs have been granted significant rights under international law (through bilateral and multilateral treaties, international trade agreements, etc.), it can be argued that such “power, authority and rights imply duties, obligations and liabilities” where TNCs are responsible for their actions (Kobrin 2009, p.13) that may result in negative outcomes.
On the other hand, some researchers believe that such responsibilities need not rest on the shoulders of corporations but should be a combined effort of other actors in the private and public sectors, including NGOs (Jamali and Mirshak 2006). Engaging CSOs/NGOs in the research design, development and implementation is also being emphasised as an effective approach of addressing issues in innovation and technology.

NGOs, have a fairly loud voice in society and can be powerful players. They are sometimes more successful in establishing regulations where governments are seen to fail (Hutter and Mahony 2004). NGOs often monitor and evaluate government policies and provide important information and alternate recommendations for policy decisions to regulators (Charnovitz 1997; Grabosky 1995; Hutter 2006). Hood et al. (2002) identified three important contributions of NGOs in regulatory debates – gathering of information, setting of standards and changing behaviours. The inclusion of NGOs in regulatory processes and standards-setting is also encouraged by international institutions like the World Bank (Deakin and Taylor 2001).

Other actors may include ethicists, philosophers and social scientists that form part of the team of natural scientists. These actors help to improve the moral debate (Zullo 2014) by engaging scientists in debates of ethical concerns and in understanding the potential impacts of their technological innovation, so as to encourage socially responsible technology development (Grunwald 2014, p.249).

Thus, the inclusion of a heterogeneous group of actors in the innovation process is crucial to the embedding of ‘responsibility’ in innovation. However, the notion of ‘responsibility’ may be understood differently by different actors within the context of emerging technologies in the food sector. Who or which actor within this food chain then decides who is ‘responsible’ for what? The question arises whether ‘responsibility’ should rest on the retailers, who are the customer-facing entities and are the ones that decide what goes on the shelves? As intermediators between the manufacturers and consumers, retailers are in a strategically important position in the innovation and production-consumption system which requires them to take ‘responsibility’ for (nano) products that go on their shelves. On the other hand, retailers know far less about the impacts of nanomaterials on human and environmental health, than do the manufacturers who source and develop ingredients of food and materials for packaging. Under these circumstances, are the retailers accountable for nanomaterials used in products, and should they be made liable for labelling these products? Or should it be the responsibility
of the manufacturers, who produce the products and know what’s in the products? Who among them would be responsible for the ‘responsible’ governance of F&FP incorporating nanotechnologies? Or should it be the responsibility of CSOs? The question again arises whether such groups have the knowledge and skills to understand the implications of risks that may be associated with new and emerging technologies. Therefore, can they be the voice of the general society? What role do they play in the governance of nanotechnologies? Also, can it be left to the political institutions alone to make decisions solely based on interactions between policy makers, researchers and scientists?

![Diagram]

**Figure 10: Example of participation of heterogeneous actors in the innovation process**

*Source: Author*
This is the case of “the problem of many hands”, an “analogous situation” whereby due to the “multiplicity of actors” involved there is no clarity as to who is responsible for what and eventually results in no one taking responsibility (van de Poel 2008). Therefore, I am interested in understanding what ‘responsible’ action means to these actors and who do they consider is ‘responsible’ for the governance of such emerging technologies as nanotechnologies.

3.2.1.4 Responsibility-Region

Normative framings of issues and technologies

There is a variety in the way ‘responsibility’ is interpreted in each region and may mean different things in different regions. Personal values and standards of morality can be quite different in the Western world from that of its Eastern counterparts. Each country may also have its own level of responsibility. Developed nations may have set very high criteria for firms in terms of their responsibility to society or may have institutionalized certain criteria for how ‘responsibility’ is practiced. For example, the way corporate social responsibility (CSR) is practiced in developed countries (Norden 2012; Maignan and Ralston 2002; Forte 2013; GoC 2014), or the institutionalization of ethics in research projects where there is an obligation on innovators to disclose any potentially high-risk components in their projects (Technology Strategy Board 2012). These levels of high responsibility may either be set by the State, or by the general society who demand greater responsibility from public as well as private entities.

On the other hand, developing countries may not have such high threshold and requirements of responsibility. Often there are preconceived notions that these economies do not meet the high ‘responsibility’ standards that are prevalent in developed countries. Therefore, developing countries are forced to adopt certain ‘responsible’ approaches as that of its Western counterpart. For example, when large IT (Information Technology) companies in the U.S. outsourced their services to software firms in India, they required CSR to be a mandatory component of the firm’s business activities.

However, such prior assumptions that Western norms should routinely be applied to developing economies are no longer acceptable. Some emerging markets are creating their own new standards of responsibility. This can be demonstrated through India’s new CSR policy (launched in April 2014), which mandates large companies to set aside a minimum of 2% of
their net profits towards CSR activities, such as for social development (GoI 2014). This new form of ‘responsibility’ is the first of its kind in the world.

In other cases, some developing/emerging countries have been seen to incorporate ‘responsible’ practices at an early stage of innovation without any intervention or pressure from the West. For example, as early as 2002, China set up a nanosafety laboratory to study the toxicity of nanomaterials (Fautz et al. 2014, p. 24), an initiative that only few developed economies focused on at the time.

Thus, such initiatives show a changing landscape in emerging/developing countries in their practices of ‘responsibility’.

It is important also to understand the perceptions of ‘responsibility’ in these regions. Science can have both positive and negative impacts, and the fast evolution of S&T must take into perspective both the acceptance and resistance towards new technologies. Often the framing of technologies is based on risk perceptions. Research shows that people accept new technologies based on the information they receive and their perception of whether it is safe (the extent of its safety and safe to the environmental) or whether it has benefits (such as nutritional value, taste/flavour, textures, convenience of use, etc.) (Bruhn 2007; Roco et al. 2011). Much of this perception is also influenced by the regulatory milieu surrounding such technologies – such as the easy availability of data on R&D involving risks, credibility of such data (be it from the government or private sectors) and “demonstrated responsibility of industry” (Bruhn 2007, p. 555). Where consumers are unable to make decisions on the safety of new and emerging technologies, technology acceptance often hinges on their trust in the experts and regulatory bodies and institutions (Siegrist and Cvetkovich 2000; Qiu et al. 2012). Those that consider the authorities ineffective to regulate or control (technological) risks are less willing to accept new technologies (Krishna and Qaim 2008, p.240). Thus, trust is an important factor that is closely linked to the perception and acceptability of various technological risks (Poortinga and Pidgeon 2005).

It has been argued that response of society to emerging technologies and how it is embedded in society differs in different countries (Swierstra and Rip 2007, p.5). For instance, the debates regarding GM are heavily focused in the developed West (Christoph et al. 2008; Magnusson and Koivisto Hursti 2002) where the benefits are seen to be less (due to availability of
alternative options), as compared to the developing/emerging countries where it focuses on benefits, especially for farmers (Krishna and Qaim 2008; Huang et al. 2006; Aerni 2001). This suggests different levels of acceptance of new technologies in different regions. For example, many studies on GM foods have shown a negative attitude towards GM technology in various developed economies like Japan, the U.S. U.K. and Europe (Yue et al. 2015; Macer et al. 2000).

These examples show that responsibility may be perceived, practiced and propagated differently in different regions. Therefore, I am interested in understanding how nanotechnology, is perceived, practiced and propagated within regions with these different approaches and understanding of responsibility. What are the ‘responsible’ measures in place for local and international firms and institutions carrying out research in nanotechnologies? How are responsibilities distributed between the actors across the two regions of my cases? These are gaps that need to be addressed. Therefore, this thesis will investigate how ‘responsibility’ is shaped by the normative framing of technology (and their interpretation of what it is to be responsible) in each region.

3.2.1.5 Responsibility – Regulation

In order to ensure ‘responsibility’ in innovations of new and emerging technologies, regulation is needed. However, often innovation is developed at a much faster pace than regulations. For example, the development of nano-products has been perceived to be growing at a much faster pace than corresponding research on EHS of the nanomaterials (Senjen 2009, p.5). Consequently, this has created a time lag between the development of inventions and emergence of nano-products in the market (von Schomberg 2013, p.19) and the associated EHS information, which has severely hampered regulatory bodies from making policy decisions on nanotechnologies due to unavailability of information (RCEP 2008).

Regulation can come from national governments but the impetus to do so could come from the stakeholders involved in the value chain through self-regulatory approaches. Much of these controls are dictated by buyers, sometimes backed by regulatory support from the government. Minimum standards of quality and safety are maintained, including by way of labelling or during processing.
However, national regulatory requirements are often set by the State and local authorities that are democratically elected. Though recent literature has shown a shift from government to governance, government still plays a dominant role in regulating National Innovation Systems. Through regulations authorities are able to enforce legislation that helps to minimise risks and stimulate innovative activities. In normal cases such classical instruments of regulation work well. However, the evolving structures of global production and R&D networks across spaces, and the uncertainties in new and emerging technologies pose new challenges for national regulation implementation and distribution of responsibility. Moreover, the cross-boundary nature of new and emerging technologies makes it difficult to rely on existing institutional division of labour, which has led to much socio-technical controversies in society (Beumer and Bhattacharya 2013, p.1). Under circumstances of regulatory and risk uncertainty no one is willing to take ‘responsibility’ and everyone tries to avoid responsibility (Pavie et al. 2014, p.10). However, someone is always held responsible in case of negative impacts.

There are various examples in the literature that illustrate difficulties in governance when there is an inter-play of multiple actors in the innovation process. Let us take for example the cases of drugs testing by leading pharmaceutical companies in developing countries in the 1990s (SOMO 2008). Clinical trials on women in Uganda taking the anti-transmission drug, Nevirapine, led to severe adverse effects and resulted in the deaths of fourteen women, which went unreported. Similarly, in India, the testing of the anti-clotting drug, Streptokinase, resulted in the deaths of eight people, who had no idea that they were used in the trials. The question in both cases is where does the responsibility lie – does the responsibility lie with the regulators because of the weak regulations prevalent in such countries or the moral responsibility of organisations?

Similarly, at one time the use of pesticide dichlorodiphenyltrichloroethane (DDT) was seen as an environmental breakthrough in the field of pesticides, leaded petrol was perceived to be advantageous and asbestos was widely used as an insulator and as a fire-proofing material. Over decades, however, various tests have revealed the negative effects of all three, DDT, leaded petrol and asbestos, to human and animal health and environment. In all these cases, it was unpredictable that the use of innovations such as DDT, lead petrol and asbestos would lead to any detrimental effects in the way that it did, however, these comparative cases highlight the unanticipated dangers and adverse effects that can be associated with new technologies.
Further, despite early warnings and demonstrable harm, decision-makers largely ignored warnings and failed to take early action.

The detrimental effects of science and technological innovations can also be seen in various other cases such as the accidents at nuclear facilities (Chernobyl, Bhopal, Fukushima), threats to the natural environment caused due to release of chemicals in the atmosphere (air and water pollution, ozone holes, climate change), and the intentional misuse of technology (the attacks on the World Trade Centre in 2001, recent cyber-attacks on Turkey by Russia, cybersecurity).

On the basis of experiences with these past cases and the ‘late lessons from early warnings’ (Steffen F Hansen et al. 2008; European Environmental Agency 2001; Maynard 2001), these examples provide important understandings of the potential pathways and consequences of new and emerging technologies.

It is extremely difficult, however, to ascertain the impacts of such new materials and technologies as nanotechnologies. Not enough is known about the impacts of new technologies, especially in the early stages of the technology, in order to be able to establish the required control measures in a timely fashion using risk-based regulatory frameworks. There is no warning of any forthcoming disasters. Thus, by the time issues of human and environmental health start to emerge the technology may already be so deeply embedded within society that it would be challenging to change it as it would lead to major disruptions. This, as Collingridge termed, is the Dilemma of Control (Collingridge 1980). Collingridge suggested that technology should be developed such that any issues that may emerge during its development can be easily corrected.

In another scenario, let us take the examples of miscarriages or birth defects in children resulting from working continuously at video display screens, or brain tumour resulting from constant use of a mobile phone or cancer from working in an area with low-intensity magnetic fields. In all these cases the cause and effect is unproven or may even be unprovable – termed as “phantom risks” (Foster et al. 1993). Under such ‘phantom’ ideas there is difficulty in bringing out regulation and therefore limits the role of regulation.

These different scenarios raise various difficulties in implementing regulation as well as in delegating responsibility. In order to be able to avoid catastrophes in an environment of
uncertainty and with no knowledge of the effects of the use of new technologies, certain risk management initiatives are required and have been developed in the form of the Precautionary Principle (von Schomberg 2006). However, as von Schomberg (2006) points out, under international agreements every country has its own right to determine the level of protection it implements (p.36). Depending on its economic situation and socio-political importance, the level of protection can either be higher or lower than the level of other nations. He goes on to stress that by incorporating the precautionary principle within its regulatory framework it does not mean that a new or stricter environment or health standard has been set but rather that it changes the way by which nations can “act when they want to implement their chosen levels of protection in an environment of scientific uncertainty”. Emerging technologies challenge various aspects of both formal legal laws and scientific knowledge. The traditional role of hard laws and the State as the implementer of these legal frameworks have somewhat blurred. Thus, in order to overcome the limitations of a top-down approach a different approach is required to govern science and innovation. Under these circumstances, it becomes necessary to recognise new forms of governance on a national and international level. Kobrin (2009) recommends a hybrid regime, which includes both public and private actors, and relies on soft law mechanisms, as a more effective tool.

In the case of nanotechnologies, by the State devolving its responsibility it invites a ‘neo-corporatist’ structure where responsibility is transferred to other actors in the food chain. Regulation is primarily set by national States and is bounded. As innovative products (and transnational firms) move in and out of different spatiality, they are subjected to different regimes of regulation and ‘responsible’ practices. For example, a multi-national corporation in a developed country such as Canada, may have to follow high standards of regulation when developing novel products. However, they may not be required to follow these high standards if they were to develop or export these same novel products in a developing country like India or China, where regulation may be lax, limited or low.

Thus, an understanding is needed how responsibility is being practiced in economies with disparate regulatory settings, and what (if any) are the existing norms and practices (hard and soft laws) that are being applied to govern products of F&FP incorporating nanotechnologies. How do the governance models differ within developed/OECD and developing/non-OECD
countries for nanotechnologies in F&FP and how is ‘responsibility’ influenced by national regulation and governance regimes? These are gaps, which need to be addressed.

3.2.1.6 Region - Regulation

Regulating in disparate institutional settings

Another challenge to regulating innovations is the difference in regulatory institutions in different economies, such as those in developing/transitioning economies.

While in economic theory innovation is often focused to developed economies and relates to progressive technologies, which creates increased competitiveness, enhanced values and economic development, a surge of researchers also recognise that innovation is gaining ground as a competitive factor in developing countries (Gellynck et al. 2011; Wolf 2007; Naudé et al. 2011; OECD 2012). Innovation in developing countries is often used to find solutions to grand challenges (Humphrey and Schmitz 2000; Henderson 2002; Aubert 2004; OECD 2011). Furthermore, there is growing involvement of various developed economies in innovation processes in developing countries/emerging economies. According to a UN Report development and security are linked and thus developed economies would be more secure if they helped poor countries meet their MDGs (United Nations 2004). There has also been significant increase in R&D capabilities in major emerging markets, which makes them a competitive destination for cross-border R&D.

However, it is important to note that policies and regulatory tools and frameworks differ across diverse countries. There is a growing body of literature that points to a weakness in the regulatory regimes of developing countries (Kirkpatrick and Parker 2004, p.41). The institutional structure of these developing countries is often considered to be weak, under-developed or even absent, and often fail to work despite importing policies that have worked in other economies (Kirkpatrick and Parker 2004). Studies have shown that regulatory bodies in low and middle income Asian economies like India have inadequate skills, various governance problems and the prevalence of ‘political capture’ (Minogue 2002). Food regulations are also often less strict in developing countries than in developed countries, hence, for example the pesticides used in these countries are often more toxic and the residue levels are usually much higher than developed countries (Krishna and Qaim 2008, p.242). Building a
‘good’ regulatory regime has thus become one of the most challenging aspects of developing countries and transition economies (Kirkpatrick and Parker 2004). Both the World Bank and the Asian Development Bank have stressed the need for improving regulatory regimes and building efficient institutional capacities in developing countries (Asian Development Bank 2000; World Bank 2001). Effective regulatory governance regimes need to be put in place if these countries want to leverage on the potentials of innovation and new technologies.

There is evidence, however, that developing countries are imbibing practices followed by advanced countries (Freeman et al. 2011). Developing countries are gaining realisation of the benefits of reforms in regulations, and implementing changes in their policies, if not from domestic pressure, then from pressures from developed countries (Guasch and Hahn 1997). Thus, while some critics argue that globalisation has opened the door to multinationals looking to establish their business in countries where regulation standards are lax due to unavailability of funds and resources (Xing and Kolstad 2002), others believe that it has enabled high standards from countries with strict regulation to developing countries where it is weak (Christmann and Taylor 2011; Drezner 2000).

Furthermore, developing countries are complying with standards set by or authored in international domains in order to compete in the global economic environment. These standards are important, especially for developing countries, because they provide access to markets, countries and the global value chain leading to international trade (Ponte and Gibbon 2005). However, producers in developing countries rarely participate in the formation of standards (Giovannucci and Ponte 2005) and this can be criticised as to whether such compliance mechanisms should be practiced in developing countries without the inclusion and participation of actors in the formation of these regulations. Moreover, standards accepted in one country may not necessarily conform to standards in others (e.g. in the case of GMO products, controls at the European Union level fell short of the World Trade Organization (WTO) law). Also, standards such as the Codex Alimentarius50, which is an internationally recognised food standard, may not necessarily conform to emerging technologies like nanotechnologies. However, while these standards and guidelines can give rise to new challenges for developing countries, it can also help raise their profile through the creation of

50 A set of internationally accepted standards, guidelines and codes of practice for ensuring food safety
better value products and co-ordination between suppliers and other actors on a global platform.

Additionally, globalisation has also compelled firms and suppliers in developing countries with low regulatory standards to self-regulate. The pressure of self-regulation depends on how much a firm wants to be accepted as a “legitimate participant” in the global economy (Christmann and Taylor 2011). The ISO management system, which endeavours to bring about co-operation in scientific, technological and economic activities across continents, is an example of meta-standards, which firms use as a starting point for self-regulation (Christmann and Taylor 2011, p.443). However, firms adopting such standards as the ISO could also only appear to be complying with regulation but may not necessarily be committed (Christmann and Taylor 2011, p.454). Moreover, it could be taken as ‘the standard’ to follow and they may not endeavour to work on other better standards. Self-regulation also may not meet the standards internationally and it could be very expensive too. On the other hand, self-regulation can provide transnational firms in developed countries, operating outside their jurisdiction, protection from future “social and environmental neglect” when operating in a region with inadequate regulation (Neilson 2008). Other, voluntary regulatory set-ups, such as the OECD and IEC, are increasingly involving emerging economies like China and India in their regulatory processes.

Nano-products are being developed in both small and large firms, some with an international foothold, and in research institutes/universities in collaboration with organisations based locally or internationally. The regions within which these R&D processes take place have different national regimes, where the governance and regulation in developed countries could be higher/advanced while those in developing countries could be lower/basic. I am therefore interested in understanding how these regulatory regimes, where the State is the legitimate actor to deal with laws, policies, legislations, etc. regulate and govern the R&D, production and movement of products incorporating nanotechnologies domestically and internationally in the absence of regulation? What are the existing governance models (hard/soft laws), and strategies for such emerging technologies in the regions of my study and how do they affect the innovation trajectory? Therefore, how do these regulations/governance models affect different geographies and markets? These gaps in knowledge need addressing, especially in the context of developing/emerging countries.
3.3 Research Questions

In the above section, the three domains of region, responsibility and regulation (R³) and their inter-relations were discussed. It is essential to examine the existing gaps in governance systems/mechanisms for emerging technologies, and notions of responsibility as perceived through actors in the innovation process, taking into perspective two diverse regimes (OECD/non-OECD economies) with disparate regulatory settings in order to be able to compare and contrast the cases of a low-regulated nation, and a high-regulated nation for ‘responsible’ R&D of innovation.

Combining these perspectives, three research questions were developed to investigate actors’ perceptions of ‘responsibility’/RI in Canada and India. These are divided into three broad categories: The first is concerned with regulations and governance structures across disparate regulatory regimes; the second is concerned with normative framings of science and technology within these separate regimes; and finally the third, looks at how these regulatory/governance structures and framings of technology through perceived notions of ‘responsibility’ affect the growth trajectory of nanotechnologies in these separate regions.

- How is the ‘responsible’ development of nanotechnologies (for food and food packaging sectors) influenced by national regulation and governance regimes?
- How is the ‘responsible’ development of nanotechnologies (for food and food packaging sectors) shaped by the normative framing of technology (and their interpretation of what it is to be responsible) in each region?
- (And therefore) How do notions of ‘responsibility’ and regulation affect different geographies and markets for nanotechnology?

3.4 Conclusion

3.4.1 Summary of this chapter

From the above we can conclude that institutional settings can differ in developed and developing countries where institutional norms and actors’ participation in the innovation process play a major role in the ‘responsible’ development and governance of new technologies. I have discussed how over the last few years, the literature on RI has been
dominated by various frameworks. I argued that while these frameworks provide some important aspects on various contexts of innovation (e.g. involvement of stakeholders in the innovation process, meeting the grand challenges, etc.), the frameworks fail to take into perspective the regional context of ‘responsibility’ in innovation and are focused to developed countries. Renn and Roco’s framework for risk governance does outline the implications of this but does not articulate how this can be applied to developing countries and emerging markets where the social values and regulatory structures are often found to be distinctly different. Their model recommends the incorporation of internationally-applicable voluntary codes, standards, certifications and/or rules for ensuring safety and risk control in the absence of regulation (Roco and Renn 2006, p.12), but does not elaborate on its applicability in diverse and fragmented institutional and regulatory structures and processes of different economies and jurisdictions. Further, their model, while focusing on early inclusion of actors in debates and discussions, was developed to address risk appraisal, and risk assessment and management for mainly industry and government officials, and thus fails to take into context the notions of ‘responsibility’ of actors and regulation in settings where risk regulation may be weak and participation of a heterogeneous group of actors in regulatory debates may be limited or absent.

It was therefore necessary to develop a more comprehensive framework, which included the regional dimension, an essential element of this study, and which can be applied universally, in developed as well as developing countries. In this chapter, I provided a conceptual framework (the R³ Framework for Responsible Innovation) that incorporated three factors – responsibility, regulation and spatialty/region - and their inter-relations – responsibility-regulation, regulation-region and region-responsibility – which I believe are essential to the governance of new technologies. Each of the six dimensions were discussed in-depth why these were important to the governance of new and emerging technologies like nanotechnologies. The R³ analytical framework, not only recognises an important role for actors in RI, but also the important role of the State in regimes with diverse institutional settings. It can therefore be hypothesised that differences in ideas of responsibilities and institutional regimes in specific spacialities (regions) are likely to shape different markets for emerging technologies. Combining these perspectives, three research questions were developed and presented to investigate actors’ perceptions of ‘responsible innovation’ in Canada and India.
3.4.2 Connecting to Chapter 4

In the following chapter I will present the methodology employed to investigate the dominant dimensions of regulation and responsibility in two regions – Canada and India, using a research design – a qualitative comparative case study analysis – which forms the basis for the collection of data in the two regions of my study.
CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

4.1.1 Connection to previous chapters

This research investigates the notion of ‘responsibility’ as it is understood and articulated by governance, corporate and various other not-for-profit organisations and civil society actors participating in markets for F&FP products incorporating nanotechnologies. It establishes how different actors and stakeholders within the nanotech food chain and in different national comparative regulatory settings discursively construct (and contest), strategically position themselves, and practically act upon the separate but related ideas of ‘responsibility’ and ‘responsible innovation’. With a focus on F&FP products, it investigates how responsibilities are construed and distributed across market and governance actors, paying particular attention to the role and influence of intermediaries such as the retailers, associations and NGOs.

In order to analyse how nanotechnologies emerge under different institutional frameworks and what it means to act ‘responsibly’ across two diverse geographical territories (Canada and India), a conceptual framework combining responsibility, regulation, and region and their inter-relations was developed and discussed in Chapter 3. A set of three research questions were also presented in Chapter 3, section 3.3, in order to compare and contrast these dimensions in two regions - a ‘less regulated’ BRICS nation (India) and a ‘highly regulated’ OECD nation, (Canada). The methodology in this chapter is used to investigate these research questions.

4.1.2 Aim of this chapter

In order to get an overall holistic idea of responsibility and explore sensitive, “ill-defined concepts” (Meyer 2001) of RI in the selected regions (India and Canada), a qualitative comparative case study research strategy was applied. As the research entails understanding

51 Formal laws, regulations, and procedures, and informal conventions, customs, and norms
the perspectives of actors and their stance on ‘responsibility’, this method was the best approach that enabled me to capture in-depth information through detailed interviews that incorporated semi-structured questions. The method provided a ‘rich’ and clear contextual understanding of the issues surrounding the ‘responsible’ development of nanotechnologies in the F&FP industries, as it is “subjectively perceived, experienced and created” (Mabry 2008) by the actors. The qualitative methodology also allowed for further probing on ideas that were shared by the participants.

The selection of a method of investigation is essential in order to be able to investigate the research questions. The thesis aims to investigate the notions of ‘responsibility’ in relevance to two regions with disparate regulatory settings. The interviews were therefore designed to ensure maximum comparability in two regions/countries where the overarching conceptual themes of regulation and ‘responsibility’ were compared and contrasted in two regions (Canada and India). Due to the globalisation of innovation, the participation of these regions, was essential to understand their role in the governance and subsequent development trajectory of nanotechnologies in an OECD and a non-OECD economy. These research questions were approached through a qualitative comparative case study analysis (QCA), a method commonly used to distinguish both similarities and differences across phenomena. QCA is a powerful tool for data exploration and to check coherence in data (Berg-schlosser et al. 2009). The analysis of data involved thematic and template analysis.

4.1.3 Chapter sections

In the following sections of this chapter, I will begin by discussing the main research methodology and the justification of the choice of a qualitative methodology in section 4.2. This will be followed by the research design and strategy in section 4.3, which includes discussing the different approaches used to select participants, tools and techniques used to collect data (i.e. the research methods), the design of the questions, the research sites, and the ethical principles applied in this study. In section 4.4, I will provide the five-stage data collection process. Following this section, in section 4.5, I will present the methods used for data analysis (thematic analysis, template analysis and comparative case study analysis), which informs my empirical studies in chapters 5 and 6. The penultimate section of this chapter,
section 4.6, outlines some of the challenges and issues faced during data collection. Finally, section 4.7 provides the concluding remarks for this chapter.

4.2 Qualitative research methodology

Primary research was carried out using a qualitative research methodology. As this research entails understanding the perspectives of actors and their positions on ‘responsibility’, this methodology was selected in order to be able to get a better understanding of the phenomenon and to capture detailed information. Moreover, this methodology provides data that is more in-depth and rich in context (Aaker et al. 2004, p.189). Qualitative research is best used where a new concept or phenomenon needs to be understood, and where not much research has been carried out (Creswell 2003; Mabry 2008). As research in the perceptions of ‘responsibility’ of actors in the nanotech food sector is limited and is fairly new, this method was the most appropriate for probing and understanding the context of the subject matter. In doing so I could get as near to the participants as possible through one-to-one interviews, which helped me obtain rich and in-depth data. Thus, the methodology was useful in gaining relevant and “concrete details” to the information I was seeking (Erickson 1986).

The qualitative methodology also provided me the flexibility to frame my questions as I went along with the interviews, so that any new information that I came across during the interview could be further broached. This interpretivist approach provided an almost present and immediate scenario of what was happening, much before analysing the full data collected from the participants. According to Mabry (2008) interpretivist researchers “follow the data where they lead” and attempt to recognise opportunities throughout the interview, where they are able to extract more information through questions rather than immediately interpreting the given information. The interpretivist approach is said to stem from a Hermeneutic52 tradition and involves interpreting deeper meaning in a discourse. It is based on the idea of multiple realities rather than one single objective reality, where in-depth enquiry and understanding, the use of multiple validities and dialogue is a focus (Denzin 2010, p.271). Qualitative researchers often adopt a form of interpretive sociology (Parkinson and Drislane 2011) where researchers study

52 The term Hermeneutics was originally used to interpret meaning within biblical text but has grown to interpret non-religious texts too to examine the underlying socio-political meaning
things in their natural settings and try to interpret its meaning through sense-making (Denzin and Lincoln 2005).

The objective of my research was to obtain a deeper and richer understanding about specific instances. By gaining detailed information, it provided me with multiple realities and with multiple quotes from participants with various perspectives, helping me gain knowledge about what is happening and how things are perceived by the actors.

The strength of qualitative research is also in its inductive approach, which helps focus on people and words rather than numbers (Maxwell 1996, pp. 22). Furthermore, as this research was exploratory, the method used was mostly inductive (Bernard 2012) as the purpose of the research was to understand and gain new information on an emerging technology. A qualitative methodology served the purpose because detailed information could be extracted from empirical interviews rather than through statistical research from which participants are most likely to deviate (Mabry 2008). This process of culling out information helped to interpret and analyse data subjectively through a thematic approach.

Qualitative research also avoids the generally poor response rate of questionnaire surveys (Austin 1981). This study involved a high participation of senior-level representatives/elites. A qualitative interviewing method, which involved personal interviews, was found to be more suitable because senior managers and officials, with very busy schedules and lifestyles, are less likely to be motivated to respond to self-completion questionnaires or tick boxes. Moreover, such responses would more likely be answered by their secretaries or staff on their behalf. Thus, using a qualitative method for my study ensured that personal perspectives were sourced directly from the participants themselves and all the questions were individually answered by each participant, which helped ensure validity of results.

4.3 Research design and strategy

Research design provides the logical processes which are taken in order to link the research questions and issues to data collection, analysis and interpretation in a coherent way (Cassell and Symon 2004, p. 326). This section provides the specific research methodology by which this study was executed, and builds on the methodological choices of this research.
4.3.1 Comparative Case Study

Comparison is an important principle of science, a crucial conceptual process and part of daily life (Caramani 1987). This study entailed examining and contrasting the disparate regulatory settings and notions of ‘responsibility’ of actors in two selected countries - India and Canada. Based on the research objective and the analytical framework as outlined in Chapter 3, and in order to gain an overall holistic view from participants in two regions, a comparative case study research strategy was used in this study.

Case studies are useful for exploring new and emerging processes (Hartley 2004, p.325). According to Yin (2003), a case study is “an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.” However, the challenge of a single case study is in disentangling and identifying information that is unique to that particular case; this however, can be strengthened by a second case (Hartley 2004, p.326). Moreover, single cases include generalizability and biases in information-processing (Eisenhardt 1989). Therefore, in this study, two cases were considered which helped to understand the “complex social phenomenon” and contribute to the knowledge of related phenomenon (Yin 2003, p.9) in disparate settings and conditions. By selecting two cases, it also helped to enhance external validity and also reduce any biases (Miles and Huberman. 1994).

An understanding of each case is important in order to be able to compare the two cases. The analytical framework set out in Chapter 3 forms the basis by which a cross-case comparison was necessary.

Comparative case studies emphasize comparison within and across contexts and show how the phenomena exists within particular cases (Stake 2000, p.444). These studies involve the analysis and synthesis of the similarities, differences and patterns across cases that share a common focus or goal (Goodrick 2005, p.7). Unique knowledge obtained from in-depth exploratory interviews with participants in the first case (Canada) was applied to examine the phenomenon in my second case (India). This helped to provide valuable contrasts and similarities in the two cases where the same themes and research questions, data collection procedures and analysis were applied so that the final results obtained from both the regions were consistent, with parallel themes (Meyer 2001). In order to generate a good understanding
of each case, methods such as fieldwork, interviews and document analysis were among the data collection methods used in this study.

While the strategies used in collecting data from a single case or comparative cases are similar, a comparative case study requires extensive conceptual, analytical and synthesising of the data. This synthesis requires work that goes beyond the basic comparison of similarities and differences. Instead these similarities and differences are used to support or contest propositions as to why an intervention may work or does not work, or why somethings succeed or do not succeed (Goodrick 2005). This requires strong synthesis skills and the ability to integrate convergent and divergent evidence to mean something. It also requires a great deal of critical reasoning and in making sense of the evidence collected so that it can be presented in a coherent argument (Spencer et al. 2003).

Comparative cast studies can also have its disadvantages. It can be resource and time-intensive due to fieldwork and in-depth synthesis of data. Findings can also be less reliable due to time lag between cases during the comparison activity.

4.3.2 Selecting samples

Participants for the interview were chosen through “purposive sampling”. The participants for the research were selected from a diverse group of actors in various roles and institutions. Williamson (1981) points out that if particular groups are unrepresented then the conclusions may not be valid and the final results could be distorted. Thus, a conscious effort was made to ensure that a variety of actor groups were represented in the selection of the sample for the interview. The samples of actors were selected based on the relevant roles of actors in various settings. These actors included:

- **Government officials** such as advisors, regulators and policy-makers from both the federal and provincial governments in Canada and the Central and State Governments in India.

- **Local manufacturers/producers** and **retailers of food products**: As important and invisible actors within the nanotech food chain, these stakeholders were included to provide important information on the use of nanotechnologies in their products and packaging.
• **Industry representatives, institutions and associations** of F&FP products (including agri-food), and those promoting and lobbying for S&T (including nanotechnologies) nationally and internationally, by way of seminars, conferences, nanotech events, etc.

• **Scientists**, which include researchers from universities as well as organisations.

• **Lawyers**, in government and university.

• **NGOs and consumer representative groups**, both local and international.

While majority of the actors were directly affiliated to roles pertaining to nanotechnologies, few actors were selected based on relevant roles in innovation, S&T, ethics or other emerging technologies such as GMO and biotechnology. This helped to maximize variation and ensure that a range of perspectives and social positions were gathered from different actors within the nanotech food sector. The selection of actors also included a breadth of senior-level officials (elites). This was necessary to ensure the information provided was up-to-date and sourced from decision-makers under whose purview decisions fell. The diverse variation in the selection of roles/responsibilities (See **Table 3**) helped to gain a wide range of perspectives and social positions from various angles, providing a broad but consistent picture of the situation in the respective regions. The range of actors selected also helped to corroborate ideas and information gathered from a diverse selection.

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**Table 3: Participant roles and responsibilities**

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<tr>
<th>Role and Title</th>
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<tr>
<td>Chairman &amp; CEO; CEO; President &amp; CEO; Chief Scientist and Chairman; Founder; Managing Director &amp; Founder - Managing Partner; Founder; Vice Chairman &amp; Chief Strategy Officer; Member Board of Directors; Member and Executive Director; Executive Director; Director; Director - S&amp;T, Director of Outreach Activities; Technical Support Director; R&amp;D Director and Chief Strategist Advisor - Strategy and External Relations; Head, Agricultural Research Systems Management and Policies Division; Senior Director - Innovation and New Technology; Sr. Director - S&amp;T &amp; Innovation; Senior Director and HOD, Nanotechnology Initiative; Director - Emerging Science; Scientific Director; Senior VP of R&amp;D; President – New Businesses and Innovation Centre; Vice-President – Public &amp; Regulatory Affairs; Vice President; Senior Science Advisor; Head, Planning &amp; Performance Division; Chief Scientist &amp; Head; Research Chair in Ethics Law in Technology, Research Chair; Head – R&amp;D Department; Head - Food Safety Services; Professor and Chair (Research) in Biomedical Ethics; Senior Program Officer, Manager Regulatory Affairs; Policy Analyst, Program Manager, Business Development Director; Business Development Manager – Nanocoatings; Senior Project Manager; Health and Environment Campaigner; Senior Scientist; Principal Scientist; Scientist, Food Science &amp; Technology; Professor &amp; Head of Department of Nano Science &amp; Technology Professor; Associate Professor; Assistant Professor; UNESCO Expert; Member - Nanotechnology Working Group of the United Nations Millennium Project Task Force on Science, Technology and Innovation; Co-Founder</td>
</tr>
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</table>
4.3.3 Research methods

Having explained the research design and processes for collecting samples in the previous section, this section outlines the methods used in collecting data, explains the design of the questions, provides information on the research sites and ethical considerations applied during the study.

4.3.3.1 Semi-structured interviews

Data was gathered through personalised interviews with participants. Semi-structured questions were used to collect data from a heterogeneous group of actors. These interviews incorporated key questions that helped to define the areas that needed to be explored. Semi-structured and open-ended questions can lead to “a voyage of discovery” and “stimulate new leads and avenues of research” (Bryman 1984). This approach was used to allow flexibility in asking questions, while also allowing the participants and myself to digress into new ideas that emerged from conversations; thus providing a wider and more descriptive understanding of perceptions of actors. The process gave participants the freedom to provide their own perspectives and me, the researcher, the freedom to explore themes that were unanticipated through further probing and questioning (Mabry 2008), especially in such new and emerging areas of nanotechnologies. This would not have been possible if I had chosen to use structured questions, which would have restricted me from probing more information gained from the answers to initial questions. In the case of unstructured questions, I would have ended up with a load of information that may not be relevant for my research. Thus, considering the constraints in time, and interviews with elite participants, semi-structured interviews provided a less rigid and a more flexible/guided approach.

While asking questions is important, listening to participants is also essential for sense-making and observation of what is going on. Corroborating the information with documentary evidence was also essential during the interviews. Hence, I had to remain alert at all times during the interviews.

As a researcher it was essential for me to have a firm grasp of the existing issues and be able to relate information and interpret it as I went along with the interviews and ask for additional evidence where the data/information was contradicting, something I would not have been able
to do using other methods. Thus, I constantly needed to make intelligent decisions about the data being collected. There is also a danger of being biased, especially when dealing with such ethical issues of nanotechnologies, and so it was important not to have preconceived notions during the interviews.

4.3.3.2 Telephone interviews

Telephone interviews were conducted from two locations – offsite from Manchester, UK, and onsite, during the fieldtrip in Canada. (See Table 4). Interviews by telephone were organised at the convenience of the participants and took place in the natural environment of the participants, their comfort zone, which allowed for easy discussions and without insecurities and discomfort. Furthermore, since the questions involved asking sensitive questions, telephone interviews were more effective as interviewees were less anxious by not having to be physically facing the interviewer. On the negative side, it was easier for some participants to terminate telephone interviews mid-way during the course of conversation. Moreover, some participants were quite expansive in their responses and it was difficult to interrupt participants if they deviated from the main area of conversation. A face-to-face interview provided a better understanding between interviewer and interviewee through body language. For example, in face-to-face interviews, if I noticed a certain enthusiasm to respond to a particular topic midway between sentences, I was able to stop and allow the participant to respond. Similarly, if the participant appeared confused or hesitated with the question, I was able to elaborate or probe into the issue, respectively.

4.3.3.3 Elite interviews

Many participants in this study included various ‘elite’ and senior level representatives from government, private organisations, not-for-profit organisations, the scientific community and other intermediaries within the nanotech F&FP sector. While there is no consensus on a definition of an ‘elite’ (Darbi and Hall 2014), for the purpose of simplicity and selection of participants, ‘elites’ in this study included those who occupied formal positions of authority within institutions and organisations (Robson 2008, p.153).

As compared to non-elites that encompass the “ordinary person” (Ostrander 1995), elites are powerful entities with “influence, control and power in a given setting” (Moore and Stokes
2012), have extensive knowledge, are good communicators and have the propensity to enhance both the quantity as well as quality of the data collected from them (Marshall and Rossman 2010; Delaney and Eckstein 2007).

It was extremely important to gain interviews from ‘elites’ for this study in order to understand the ‘behind the scene’ situation on aspects of regulation and ‘responsibility’ pertaining to nanotechnologies. Elite interviews can provide new information that only elites have access to and may not be found anywhere else (Darbi and Hall 2014; Lilleker 2003). However, one has to be cautious on the information gained as sometimes it may be exaggerated or even false (Lilleker 2003, p.208). Under such circumstances, the process of triangulating\textsuperscript{53} data during the research process becomes essential (Marshall and Rossman 2010, p.254) which involved corroborating earlier findings from secondary sources and cross-check information through multiple sources to reveal weak links, thus increasing the credibility of findings.

4.3.4 Designing questions

One of the most important aspects of data collection was to put together a set of relevant questions based on what I wanted to learn from the outcome of the interviews. Research questions were organised under the three key themes of responsibility, regulation and markets as outlined in the conceptual framework in Chapter 3. To ensure accuracy in data, inductive questions were also based on the individual participant’s role/area (Easterby-Smith, Thorpe & Jackson, 2008). The questions were designed such that they could be easily modified to address different actor groups. For example, questions for organisations and scientists had to be slightly modified to address issues relevant to them as compared to regulatory officials. The questions were also prepared with some useful prompts to encourage the participant to discuss specific issues that they did not spontaneously talk about. Often interviewees are unaware of the expectation to be expansive in their answers and such prompts help to expand further their reflections on the topic (Bryman 2012). Furthermore, the open-ended, discursive nature of the interviews permitted me to identify and pursue new and complimentary issues raised by earlier interviewees, and presented and probed in later interviews (Beardsworth and Kell 1992)

\textsuperscript{53} Bring more than one source of information to understand or corroborate a single point (Marshall and Rossman 2010)
A sample of the questions has been provided in Appendix 1.

4.3.5 Research sites

The research was undertaken in India, an OECD-interest country, and Canada, one of the founders of the OECD. The rationale for choosing the two cases for this research has already been provided in detail in Chapter 1, section 1.2.

4.3.6 Ethical considerations

As this research entailed various social, environmental and ethical issues pertaining to nanotechnologies in F&FP, some participants did not want to be identified. In such instances participants were assured of confidentiality of data at all stages of the interview. Elites are especially wary about what is put on record since some of the information provided by them can damage their official status and influence (Kezar 2003). For example, a participant from a government agency in India, refused to be recorded, whose demands was met. It was thus very crucial for me, as a researcher, to assure the potential participants of the confidentiality of data collected. This was largely achieved during the initial contact, which explicitly outlined the confidentiality protocols that would be followed during the interview and provided the Participation Information Sheet detailing the research and process of interviews. The ethics form that was provided to each participant outlined researcher responsibilities and ethical considerations such as the ability of the participant to withdraw from the research at any point of the interview without giving a reason and without any detriment to them. Initial contact mails to potential participants in food companies provided additional assurances of data protection and protection of company name.

4.4 Data collection

4.4.1 The data collection process

The data for this study was collected from two regions – Canada and India (See Table 4).

Data collection in Canada comprised forty four interviews; nineteen interviews were collected by telephone from the UK and one was collected by email. During a field trip to Canada in
September 2012 an additional twenty two interviews were carried out face-to-face in various cities in Canada (Toronto, Mississauga, Guelph, Ottawa, Markham and Montreal) and two were collected by telephone. Interviews lasted 1 (mostly) -1.5 hours.

In India a total of twenty six interviews were carried out. The first five interviews in India were conducted by telephone as a pilot study from Manchester, UK, in 2012. An additional twenty one interviews were carried out in 2013, after the completion and initial analysis of the interviews in Canada. Due to the lack of funding for fieldwork in India, most of the interviews were conducted by telephone from Manchester, UK. Interviews lasted 1.5 (mostly) - 2.0 hours.

(Appendix 18 provides a list of the agencies and organisations from where participants were interviewed.)

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>METHOD</th>
<th>CANADA</th>
<th>INDIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONSITE - CANADA</td>
<td>Face-to-face</td>
<td>22</td>
<td>00</td>
</tr>
<tr>
<td></td>
<td>Tel</td>
<td>02</td>
<td>00</td>
</tr>
<tr>
<td>OFFSITE - UK</td>
<td>Tel</td>
<td>19</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Email</td>
<td>01</td>
<td>01</td>
</tr>
<tr>
<td></td>
<td>Skype</td>
<td>00</td>
<td>01</td>
</tr>
<tr>
<td>TOTAL NO. OF INTERVIEWS</td>
<td>44</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Total number of participants interviewed face-to-face/telephone/email in Canada and India

Majority of the participants in India were interviewed by telephone and one was interviewed over Skype as it was requested by the participant. In contrast, participants in Canada were interviewed by telephone as well as face-to-face. These methods enabled ease of conversation and made participants comfortable within their environment. All the interviews were recorded using a digital recording device (dictaphone) with the permission of the participants. Two of
the participants, one from Canada and another from India, who were unwilling to participate in interviews by telephone or face-to-face, opted to answer questions via email. However, this was quite restrictive as the ‘structured’ nature of the questions did not allow me to probe further, unlike telephone and face-to-face interviews. Nevertheless, they still provided detailed and useful information for this research.

The wide selection of participants, as outlined in section 4.3.2, helped to maximize variation (see Table 5 for breakdown of actor groups). It also allowed me, as the researcher, to get diverse and distinct views and perspectives and understand each actor’s social position within the food chain. In order to build trust and realise the limited time gained for an interview with organisations, and the slim possibility of getting a second interview with elites, questions of ‘responsibility’ which may appear to be ‘threatening’ for firms/organisations due to the ethical issues surrounding nanotechnologies, were left to the end of the interview process (Robson 2008). By re-ordering the questions (Costa and Kiss 2011), it helped me to cover much of the other areas of the questions without discomforting the interviewee.

<table>
<thead>
<tr>
<th>ACTOR GROUPS</th>
<th>CANADA</th>
<th>INDIA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOVERNMENT (policy-makers, regulators, funders)</td>
<td>16</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>NOT FOR PROFIT ORGANISATIONS / ASSOCIATIONS</td>
<td>06</td>
<td>02</td>
<td>08</td>
</tr>
<tr>
<td>ORGANISATIONS (small/large, retailers, manufacturers/producers)</td>
<td>05</td>
<td>06</td>
<td>11</td>
</tr>
<tr>
<td>CSOs / NGOs / CONSUMER REPRESENTATIVE GROUPS</td>
<td>03</td>
<td>01</td>
<td>04</td>
</tr>
<tr>
<td>UNIVERSITIES (lawyers, scientists, ethicists, etc.)</td>
<td>14</td>
<td>07</td>
<td>20</td>
</tr>
<tr>
<td>TOTAL NO. OF INTERVIEWEES</td>
<td>44</td>
<td>26</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 5: Breakdown of actors interviewed in each region
The collection of data was carried out in five stages - a pre-interview stage, the pilot stage the offsite interview stage, the onsite interview stage/fieldwork and the post-fieldtrip stage. During these five stages, data from the participants were collected by telephone, face-to-face, email and in one case by Skype.

4.4.1.1 Pre-interview stage

Secondary research
Prior to beginning interviews and going out on fieldwork for data collection, an in-depth web-based research was carried out. This involved web-based scoping for information with regards to the regulatory position and trends on nanotechnologies in the F&FP sectors in India and Canada. It also involved identifying organisations and potential participants and experts for the research – who they are, what their roles are in the R&D and regulation of nanotechnologies, and what is the role of the organisation/institution where they work? In order to carry out interviews effectively, it was essential to gain maximum knowledge about the participants’ position/title, role and achievements so that questions could be asked based on their expertise (Costa and Kiss 2011; Kezar 2003). It was also important to be well equipped with the understanding of the link between the theoretical issues being studied and the data collected to ensure the right type of actors were identified and the right type of data was collected. Journals/academic papers/articles, conference papers, reports and presentations, government institute and agency websites and directories, nanotechnology-related websites, websites of specific government organisations, intermediary institutions and companies, annual reports, e-magazines, social media sites such as LinkedIn and Twitter, media stories/press releases, NGO, industry and analyst (research) reports and other relevant documents and vehicles of communication were used for information gathering and identifying the ‘right’ participants. Publicly available directories for contact details was also used to identify elites (Lilleker 2003; Darbi and Hall 2014). Interestingly, it was easier to get the contacts of elites in Canada than those in India due to publicly available information. Thus, this stage helped to create a case file for each potential participant and their organisation in the two regions, Canada and India.
Request for interviews

The first contact with participants was made by email. Identified participants were sent a personal email (See Appendix 21 for sample of email) which gave a brief description about this study’s aim and requested for a telephone interview. The email included a Participant Information Sheet and Consent Form, which provided further details on the research, the author, participant’s ethical considerations and confidentiality position, and request for their consent for the interview.

In case there were no responses to the first email, the email was followed up by a second email and subsequent telephone call, where necessary. Easterby-Smith & Lowe (1991) suggests that a second (reminder) email followed by a phone call helps to establish contacts.

Besides emails and telephone calls, some participants were also contacted through social media sites like LinkedIn and Twitter, where I was unable to obtain the direct contact details of participants (e.g. a Minister). A database was created of up to two hundred potential participants. A diary of those that were contacted and those that responded was also maintained at all times to ensure regular follow-ups.

4.4.1.2 Snow-balling

A large number of participants were contacted through snow-balling and personal referrals. This method helped to identify key actors and experts within the nanotech food chain through intermediary and mutual contacts that may have been missed during the scoping process. Moreover, it helped to corroborate the contacts with my personal list of identified as ‘important’ potential participants and therefore helped to get the perspectives from the people that ‘matter’ the most within the area/industry. Thus, snow-balling helped to target the right people resulting in rich and accurate data.

Having good formal and informal contacts was vital to gaining access to elite interviewees (Costa and Kiss 2011; Lilleker 2003), especially in Canadian F&FP organisations who were unwilling to speak about nanotechnologies for fear of being identified/tagged as a potential user of nanotechnologies. Approaching them through a reference made them comfortable about
sharing their perspectives more openly, though I had to sign confidentiality agreements with some participants before the interview.

4.4.1.3 Pilot stage

The pilot stage was initiated with a ‘test’ interview with a company in the UK, doing business with a Canadian nanotech firm involved in packaging, which was later discarded. Data was then collected from five participants in Canada via telephone from Manchester.

In order to get a sound understanding of the existing regulatory system and validate information from secondary research, five government officials in Canada were interviewed first. This provided an initial understanding of the regulatory system in Canada and a base from which interviews with other actors was later conducted.

The decision to interview participants from Canada first was because Canada is at an advance stage of R&D in nanotechnologies, and I considered that it was better and more useful to study the case that was ‘full’ (Canada) than a case that was ‘half empty’ (India). Bagged with extensive information from a ‘full’ case, it was easier to discuss and probe participants in India.

4.4.1.4 Offsite interviews

Following the initial scoping in Canada, and after a preliminary analysis of the five pilot interviews in Canada, a further group of fifteen participants from Canada were interviewed, taking care to include actors in a variety of roles, organisations and regions.

Five interviews were also conducted in India to get an understanding of the existing scenario in India. This involved interviews with participants from small organisations as they were easily approachable and quick to respond.

These were conducted via telephone from Manchester.
4.4.1.5 Onsite interviews/fieldwork

The offsite stage was followed by fieldwork in Canada to collect the remaining data from additional participants. This stage involved interviewing relevant actors onsite in Canada, especially those that did not respond to emails or phone calls during the offsite stage, and those in government and universities that were more keen to speak face-to-face than by telephone.

Participants were first contacted by email for an interview from Manchester, before leaving on fieldwork and appointments were confirmed based on their availability. Many of the participants that were sourced through snowballing whilst in Canada were also first contacted by email and followed up by telephone for a confirmation and appointment. The field research also gave me the opportunity to identify and successfully interview participants from relevant companies and universities, with an interest in nanotechnology. The interviews were either carried out face-to-face or via telephone depending on participant comfort.

Face-to-face interviews provided a more personal interaction, which helped to ‘connect’ with potential participants onsite. As this research included various questions on the social and ethical issues of nanotechnologies, it was also essential to build a ‘relationship’ and a positive rapport with the participants. Establishing a bond, especially with elites, is as important as getting the interview in order to gain quality data (Darbi and Hall 2014, p. 840). Thus, such face-to-face interactions did not only help break the ice between the researcher and participant but also helped ensure data credibility (Creswell and Miller 2000, p.128). Moreover, there was also a willingness by the interviewees to refer me to their colleagues working within the company or institute for an interview. Also, by being on location, I was able to gauge first-hand the state of nanotechnologies in F&FP (and agriculture) and was even taken on a quick field trip to an orchard by a participant working on nanotechnology. I was also able to obtain numerous hard copies of essential documents from participants, which were not available online.

4.4.1.6 Post-fieldtrip interview

After collecting all of the data from Canada, a preliminary analysis was undertaken (The method used for analysing data is explained in detail in section 4.5). This process helped to investigate new findings in Canada and include questions for Indian participants that did not
form part of the initial set of questions. As pointed out by Scapens et al. (2002), the “missing connections” and “inconsistencies” obtained from the initial set of interviews during field scoping can be determined and corrected in the second set of interviews. Thus, for the interviews in India, I was able to modify my questions slightly to include additional questions incorporating new findings that emerged from my initial round of interviews in Canada.

4.5 Data analysis

The data analysis process is all about data reduction where there is a grouping of textual data to help make sense of information provided (Bryman 2012). The analysis of data in this research involved various processes (See Figure 11):

i. Transcribing data

ii. Thematic analysis

iii. Coding of data using template analysis

iv. Comparative case study analysis

![Figure 11: Process for analysing data](source: Author)
4.5.1 **Transcribing data to enable in-depth analysis**

All the interviews that were recorded using a digital record for superior recording quality were transcribed. Transcribing is also advantageous as it provides an alternative solution to the limitations and dependence on our memories to recall aspects of the interview and allows detailed and in-depth examination of what participants said (Heritage 1984). However, six interviews were not transcribed. These included a participant in India from a government agency who did not wish to be recorded; an interview with an Indian participant when the recorders failed to save the data; an interview with another Indian participant where the quality of sound was incomprehensible due to background noise and thus was discarded; the two responses received via email. A sixth interview (not included in the list of total number of interviews), which was used as a first pilot in the UK was discarded because it was a UK-based organisation, which was not a region of interest for this study. For the two interviews that were not recorded the interview diary maintained after the interviews, provided the data.

The process of transcription was long and tedious, taking a few months, but necessary to enable in-depth analysis. By transcribing all the data, I was able to get close to the data and also refer to the text continuously for specific themes and ideas. Transcribing the data also enabled me to mark text that were important and related to a particular discussion.

4.5.2 **Thematic analysis of data**

Themes are “fuzzy” and “abstract” constructs that are identified before (through literature review), during or after the study (Ryan and Bernard 2000, p. 780) p.780. Thematic analysis involved an initial preliminary observation of the data followed by detailed analysis, which incorporated careful examination of all the data that was transcribed to identify the main/core themes and patterns that emerged from the interviews. The ongoing activity for analysis was important because it allowed me to be aware of new and emerging themes, which I could probe into in later interviews. This was achieved by looking through the transcribed interviews individually and picking out and listing sub-themes that appeared under the main themes of my interview questions - regulation, responsibility and markets. For example, Canada’s regulatory stance, ‘perceptions of responsibility’, ‘who is responsible’, ‘markets for nanotechnologies’, etc.
4.5.3 Template analysis

Template analysis involves flexible techniques for thematically organizing and analysing textual data (King 2004, p.256). In this study the data under each conceptual theme was further categorised and defined into codes (‘template’) and levels of sub-codes, creating a hierarchical structure (Ryan and Bernard 2000). The initial template thus comprised of higher-order codes, which was further divided into as many lower-order codes. The depth of the lower-order codes helped refine data providing a finely-grained analysis of the phenomena. It was essential to ensure that these codes and sub-codes had direct relevance to the study’s key objective and research questions (King 2004, p.261). Textual data was then highlighted in individual transcripts that was relevant to the research questions and placed under specific codes and sub-codes in a separate document. This was done for all the transcribed interviews. During this process any new themes that emerged were added as new codes. The process also included deleting codes where it was of limited/no use and changing codes into a new higher/lower order or a different order where it might fit better (King 2004, p.262).

After the completion of the first stage of analysis, involving data management, sorting and synthesis of the data, the next stage comprised the interpretation of the data. This involved “making sense” of the findings through “descriptive and explanatory” processes (Ritchie et al. 2003). The coded document/template was used to look for patterns, recurrences and links that appeared across the interviews in order to build an understanding of the phenomena under investigation. This also involved picking out “unusual terms” or common words and phrases used by different participants (Bernard 2012). In this research, much attention was given to how specific actor groups and individual actors related to a particular topic, or how and if their views inter-related to each other. For example, in the perceptions of ‘who is responsible for the governance of nanofood products’, specific attention was given to who each actor group thought was responsible, and whether that group considered themselves responsible or pointed the responsibility elsewhere. This group-to-group validation was necessary for reliability of the data. Thus, corroboration of data was an important aspect of the analysis. To increase the robustness of the findings, the process of triangulation was used, which allowed cross-checking of data through various sources, including literature, to form themes and categories in the study (Creswell and Miller 2000, p.127).
<table>
<thead>
<tr>
<th>CODE</th>
<th>FOCUS ON/AS</th>
<th>CODE</th>
<th>FOCUS ON/AS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADV</td>
<td>Advisor</td>
<td>NANO</td>
<td>Nanotechnology</td>
</tr>
<tr>
<td>AGRI</td>
<td>Agriculture</td>
<td>NFP</td>
<td>Not-for-profit</td>
</tr>
<tr>
<td>ASSO</td>
<td>Association</td>
<td>NGO</td>
<td>Non-governmental organisations</td>
</tr>
<tr>
<td>CAN</td>
<td>Canada</td>
<td>NOV</td>
<td>November</td>
</tr>
<tr>
<td>CC</td>
<td>Consumer Group</td>
<td>ORG</td>
<td>Organisation</td>
</tr>
<tr>
<td>CNST</td>
<td>Consulting</td>
<td>OWN</td>
<td>Owner</td>
</tr>
<tr>
<td>DIR</td>
<td>Director</td>
<td>PKG</td>
<td>Packaging</td>
</tr>
<tr>
<td>EMG</td>
<td>Emerging Technologies</td>
<td>POL</td>
<td>Involved in policy-making</td>
</tr>
<tr>
<td>ETH</td>
<td>Ethics</td>
<td>PRO</td>
<td>Promoter</td>
</tr>
<tr>
<td>FD</td>
<td>Founder</td>
<td>R&amp;D</td>
<td>Research &amp; Development</td>
</tr>
<tr>
<td>FF</td>
<td>Face-to-face</td>
<td>REG</td>
<td>Regulation</td>
</tr>
<tr>
<td>F&amp;P</td>
<td>Food &amp; Packaging</td>
<td>RES</td>
<td>Research</td>
</tr>
<tr>
<td>FS</td>
<td>Food safety</td>
<td>RET</td>
<td>Retail</td>
</tr>
<tr>
<td>FUN</td>
<td>Funding</td>
<td>SEPT</td>
<td>September</td>
</tr>
<tr>
<td>GM</td>
<td>Genetically modified foods</td>
<td>S&amp;T</td>
<td>Science &amp; Technology</td>
</tr>
<tr>
<td>GOV</td>
<td>Government</td>
<td>SCI</td>
<td>Scientist</td>
</tr>
<tr>
<td>FOOD</td>
<td>Focusing on food/food</td>
<td>SCN</td>
<td>Science</td>
</tr>
<tr>
<td></td>
<td>department/division</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6: Acronyms for interview codes

<table>
<thead>
<tr>
<th>IND</th>
<th>SKP</th>
<th>IP</th>
<th>SR</th>
<th>INT</th>
<th>STAND</th>
<th>INST</th>
<th>STGY</th>
<th>JUN</th>
<th>TEL</th>
<th>LAW</th>
<th>TOX</th>
<th>MAN</th>
<th>UNI</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>Skype</td>
<td>Intellectual Property</td>
<td>Senior/Elite</td>
<td>International focus</td>
<td>Standards</td>
<td>Research institution</td>
<td>Strategy</td>
<td>June</td>
<td>Telephone</td>
<td>Dealing with law/lawyer</td>
<td>Toxicity</td>
<td>Management</td>
<td>University</td>
</tr>
</tbody>
</table>

For the sake of anonymity, as requested by participants, each participant has been provided with a ‘code name’, which provides readers an understanding into the roles/responsibilities and institutions/organisations of the participants. For example, GOV/FUN/POL/17SEPT12/FF/CAN means the participant is a government official (GOV) in a funding agency (FUN) in Canada (CAN), involved in policy-making (POL), and was interviewed face-to-face (FF) on 17 September 2012 (17SEPT12). (See Table 6 for acronyms used in interview codes).

4.5.4 Comparative case study analysis

According to Stake (2000, p.444), comparison is a “grand epistemological strategy” and a “powerful conceptual mechanism” that helps to identify various attributes. A (qualitative) comparative case study analysis of the analysed interviews/data from both India and Canada was undertaken based on the findings from each region to investigate similarities and differences. This method involved a synthesis of the findings (Yin 2009) from each case.
A comparative case study analysis was carried out in order to compare (and contrast) the notions of ‘responsibility’ through the perspectives of actors in two countries with totally different regulatory settings - India, a developing country with potentially limited/low regulatory standards, and Canada, a developed country which is considered potentially to have high regulatory standards. This comparison helped not only to bring forward the differences and similarities of nanotechnology R&D processes within the two regions, but also provided an insight into the positions of actors pertaining to what ‘responsibility’ or responsible innovation means to them, keeping in mind that they are situated in an environment with different regulatory regimes and social norms. Questions were thus asked in such a way so as to be able to gain information in a “consistent and comparable” manner (Scapens et al, 2002).

4.6 Challenges and limitations

There were various challenges faced by the author during the collection of data in Canada and India.

i. *Delays in participant contact and confirmation:* While setting up interviews with participants in Canada was fairly easy where an appointment for an interview was usually made within 1-7 days from the date of first request, making contact and setting up interviews with potential participants in India turned out to be a daunting task, especially as many of the potential participants that were contacted were elites with highly busy schedules and gaining an interview with them was difficult (Marshall and Rossman 2010; Kezar 2003). Requests for interviews were often ignored and responses by email were rare or completely absent. Moreover, numerable phone calls resulted in no definite confirmations. Access to senior executives and government officials were especially challenging as it involved multiple gatekeepers and calls made to their offices were often directed to secretaries and other staff that were unwilling to confirm appointments. Where interviews were successfully scheduled, it often resulted in ‘no shows’ of participants, postponements or cancellations without notification. A re-confirmation of interview schedules did not avoid such absenteeism. As Welch et al (2002) points out absenteeism, cancellations and time allotment issues often result due to the busy schedules of potential participants.
ii. **Limited time and resources:** Besides the delays in confirming interviews, as discussed above, lack of funding towards fieldwork and travel to India also contributed to the delays in conducting interviews in India. While telephone interviews can cut travel costs and other expenses required during site visits, it created huge challenges in connecting with participants remotely due to time zone differences and limited use of email by a vast majority of potential participants. Moreover, considering India’s cultural differences, it would have been easier to contact and connect with potential participants face-to-face rather than remotely.

iii. **Time zone differences:** There were few challenges in organising interviews between the two regions due to the difference in time zones. While India was (4.5-5.5 hours) ahead in time, Canada was (4-5 hours) behind UK time. This meant that sometimes interviews had to be conducted outside of office hours of the University. Often this resulted in phone lines and offices not being opened and unavailability of university IT staff responsible to rectify any technical issues. Moreover, despite scheduling the interviews for one hour, interviews often extended beyond the scheduled time. Thus, only a limited number of interviews could be organised per day in order to avoid overlaps of interviews/appointments.

iv. **Long distance travel:** As an interviewer, I also faced some challenges when it came to control over choice of arranging an interview in a particular place (Ostrander 1993) and had to often contend with travelling long distances and locating interview sites in remote/isolated places in Canada during fieldwork in Canada. This also meant that often only one interview was conducted per day or per two days as time was needed to organise or travel to the next location of interview, or set up new interviews.

v. **Technical problems:** There were various technical issues that compromised the effective flow of interviews. For example, the digital recorder used for recording the interview sometimes failed to work or did not record some days. Under such circumstances, the author had to rely on notes made immediately after the interview. Also, interviews conducted by telephone in India often disconnected several times, which disrupted the interview flow and conversation. Alternative forms, such as Skype, too were unreliable and calls dropped often. Several participants in India that were
contacted on their mobile phones (on their request) had very bad coverage and conversations were often unclear. A few participants took the calls outside their workplace or whilst they were travelling, which resulted in lots of background noise and conversations were sometimes incomprehensible.

4.7 Conclusions

4.7.1 Methodological reflections

The main aim of this Chapter was to provide information on the empirical approach used to collect data for this study. This Chapter, therefore, provided the main methodology used to gather empirical data for this study (qualitative), the research methods used to collect this data (in particular semi-structured, telephone, face-to-face, elite interviews), and the systematic process of data analysis (synthesising data through thematic analysis, template analysis and comparative case study analysis). Since, the main aim of this study was to explore the notions of ‘responsibility’/responsible innovation in two distinctively diverse regulatory settings, it was essential to use a methodology that would enable an explorative approach. As the study of notions of ‘responsibility’ in nanotechnologies, specifically in F&FP, is very underdeveloped, the selection of a qualitative approach and semi-structured interview method as against a quantitative, survey approach, was justifiable in the context of this study, which provided in-depth views of interviewees. This choice of methodology thus helped to obtain detailed information on the phenomena being explored. This is particularly useful when exploring new phenomena, in this case the notions of ‘responsibility’ pertaining to nanotechnologies in F&FP.

4.7.2 Connecting to Chapter 5 & 6

Following on from the methodology chapter, the following two chapters, Chapters 5 and 6, provide the findings from the empirical data collected from Canada (Chapter 5) and India (Chapter 6). In both cases, the data is analysed using conceptual themes from the conceptual framework in Chapter 3, using the three dimensions of regulation, responsibility and region (i.e. markets of nanotechnologies). The results of the analysis of both cases are presented through five scenarios of a governance approach found within each region.
CHAPTER 5

FINDINGS & ANALYSIS - THE CASE OF CANADA

5.1 Introduction

5.1.1 Connection to previous chapters

In the previous chapter, I provided the main research methodology and methods used to collect and analyse data to explore notions of ‘responsibility’ of actors in two diverse regulatory economies. In Chapter 4, I also provided a list of participant roles in various departments within their institutes, universities and organisations that were contacted and interviewed for this study (See Table 3 and Table 1754).

5.1.2 Aim of this chapter

In this chapter I will provide a detailed analysis of interviews that was conducted in my first case, Canada. This chapter draws on the findings of interviews conducted during the period May 2012 to November 2012. The interviews provide an understanding into the perceptions of actors within the nanotechnologies F&FP (and agri-food) industry in Canada. It provides an overview of the existing support and trends in R&D of nanotechnologies in Canada, actors’ articulations on the current state of regulation, and their notions of ‘responsibility’ for the governance of nanotechnologies as perceived through the lens of a diverse group of actors.

It was essential to include participants from various backgrounds and roles within the F&FP area in order to gain a wide and varied view of the existing setup pertaining to nanotechnologies in Canada. There was an attempt to select a heterogeneous group of actors with views and activities related to the development and/or research of nanotechnologies specifically. Where these roles were absent in certain organisations and institutions, or were not specific to nanotechnologies, the actors were selected for their roles in S&T involving R&D of emerging technologies and/or ethics. While the inclusion of actors from both the public and private sectors was important, over the months, it became quite obvious that it was also essential to

54 In Appendix 18
ensure that these actors were selected across different provinces of Canada in order to incorporate views and get in-depth understanding of the state of affairs in Canada. A total of forty-four participants were interviewed from Canada, including government officials, manufacturers/producers, retailers, representatives from not-for-profit/non-governmental organisations and industry associations, scientists, lawyers, ethicists and CSOs/NGOs.

The direct quotes of actors have been cited in italics in inverted commas. It is essential to note that due to the limit on word count in a thesis, most of the quotes have been used directly in sentences in order to demonstrate the views of different actor groups. To maintain participants’ anonymity, each interviewee was given a code (explained in detail in Chapter 4, section 4.5.3) based on where they worked, specific area/department or seniority of their role (if any) and their role in the organisation. Words/phrases in square brackets used in between these quotations refer to absent words added by the author.

5.1.3 Chapter sections

In Section 5.2, I begin by recording the perceptions of actors on the current state of nanotechnologies in Canada. This section focuses on the role of government in supporting R&D of nanotechnologies, including in F&FP and agri-food sectors, through the development of infrastructure and funding of fundamental research projects. In section 5.3, I will discuss the main findings around existing perceptions on the regulatory regime and protocols for F&FP in Canada. This section also provides information on the deliberations on international collaborations for regulations, actors’ involvement in policy debates and discussions and challenges of EHS/ELSI. I then proceed to section 5.4, which provides a narrative on actors’ perceptions of ‘responsibility’/RI and who they perceive is ‘responsible’ for the ‘responsible’ governance of nanotechnologies. Section 5.5 provides an overview of existing R&D projects and collaborations in nanotechnologies in the F&FP sectors as discussed with various actors, including in agriculture, which forms part of the food chain. It focuses on a collaborative project with India. Finally, in section 5.6, I conclude this chapter by providing a summary of the analysed findings based around five main avenues in Canada.
5.2 Supporting R&D of nanotechnologies

5.2.1 Canada’s interest in nanotechnologies

Participants in this study stressed that the Government of Canada (GoC), both the federal and provincial governments, is putting huge efforts in providing financial support towards infrastructure and equipment to carry out R&D in S&T at universities and research institutes.

Funding for nano-related R&D in F&FP, including agriculture is provided by both, the federal and provincial governments. A majority of the funding comes from the provincial government, which are available to universities (mainly), research institutes and corporations. The study found that some scientists at universities receive grants not only from the Canadian government, but also the U.S. government.

According to a government official, funding towards nanotechnologies R&D has increased over the last decade.

“And the funding has gone up, no it's continued to increase over the last decade or so.” (GOV/PRO/ADV/18SEPT12/FF/CAN)

Some scientists that were previously working as researchers at universities in the U.S., pointed out that there is more support in Canada where the government is “trying to distribute the funds as much as it can.” (UNI/SCI/24SEPT12/FF/CAN), than the U.S. where normally a big fund is provided for only a limited number of scientists. Scientists working in one province are also often supported by the government from a different province. National funding for research from university sources like National Council of Educational Research and Training (NCERT) are also available. Funding can be extended if researchers are able to show successful research outputs.

However, according to some participants, there has been recent cuts towards funding of S&T projects, including those in nanotechnology. The (new) Harper government’s S&T strategy has reduced or suspended funding for such projects that did not show immediate returns on investment, especially in food or agriculture technology. Thus, programs such as the Strategic Grant Program that supported food-based technology “has decreased somewhat”
However, the GoC is seen to encourage international co-operation and initiation of joint projects on S&T. Canada has signed many bilateral S&T agreements with numerous OECD countries, such as Germany, France, and countries in the EU, and more recently, with non-OECD countries like India, China and Brazil. Some of the priority areas in these agreements includes focus on different projects on nanotechnologies.

5.3 Regulating nanotechnologies in Canada

In the following section, I investigate the existing regulatory structure within Canada for food and food packaging incorporating nanotechnologies (F&FPN). The purpose of this section is to investigate and understand what are the existing policies for nanotechnologies in Canada; which are the main agencies that are responsible for the regulation of nanotechnologies; who are the actors involved in policy-making; what are the challenges of governing nanotechnologies in F&FP; and what are the perceptions of actors (including firms and NGOs) with regards to the governance of nanotechnologies in F&FP?

5.3.1 Comparison with EU

There are no regulations for nanotechnologies in F&FP and there is much debate within government whether there should be specific regulations for nanotechnologies. As one respondent from a government agency put it, without a government position:

“It’s a bit like the ‘Emperor with no clothes’.” (GOV/PRO/ADV/18SEPT12/FF/CAN)

The general view among a large majority of participants was that “Europe is several steps ahead” (NGO/NANO/31MAY12/TEL) and there is “a lot more done” in Europe in terms of addressing issues and governance of nanotechnologies, while “Canada is way behind...probably zero.” (CC/REP/29MAY12/TEL). According to participants, the laws in Canada are “full of holes” (GOV/INST/SR/ETH/6NOV12/CAN) and products can easily find their way into the market, and so “the government [in Canada] needs to wake up.” (UNI/SCI/27SEPT12/FF/CAN) and take a similar lead on regulations as has Europe.
Furthermore, public debates around nanotechnologies in Canada “is not as public as it is in Europe”. While there are initiatives to develop a regulatory framework with the U.S., participants point out that the U.S. are “not really strong on nanotechnology regulations” either and Europe is “more strict” (GOV/FUN/POL/17SEPT12/FF/CAN) than North America.

A scientist stressed that it would be difficult for the government to really be effective in regulation at this point, and it would be difficult to develop regulations at this point in time because there is “not much experience about the use of nanotechnology in food” (UNI/SCI/24SEPT12/FF/CAN) nor have there been any incidences for them to address the problem.

However, it is the intention of Health Canada to put in place regulatory frameworks for nanotechnologies, though participants pointed to cutbacks that have hindered progress. Guidelines are in the process of being developed by the CFIA, HC and EC. Regular updates are also being made to food regulations on a case-by-case basis. For example, recently, nanocrystalline cellulose was given the green signal in Canada for use in nano-packaging materials (though it has not yet been approved to be used in nano-food products.) According to an ethicist nano-cellulose is a “great priority for the government” as it is seen “to create wealth” for the wood industry and help them “get back on its feet”.

5.3.2 Stringent regulations and policies

The study found that regulations for F&FP products, including new and innovative products, are very stringent and considered by participants to be much higher than many other countries. For example, there is zero tolerance policy with regards to the presence of insects per kilogram of any grain that is exported out of Canada, whereas the U.S. allows 3-5 insects.

New and emerging technologies that have, or potentially have, any influence on health and safety are often subjected to tough regulatory protocols. The food industry, specifically, is “quite well regulated” (GOV/FUN/POL/17SEPT12/FF/CAN) and there are plenty of regulations in place to stop companies from taking a product and putting it on the market directly without any testing. This was consistent among various actor groups, and confirmed by regulatory agencies that the Canadian regulatory system for food (including novel foods) is “very strict” (INST/SCI/8NOV12/FF/CAN) and sometimes “a bit overzealous”
In order to introduce new products or new ingredients, organisations are often required to go through “very lengthy process[es]” to “showcase that [they] are in compliance with the regulations and the laws applied” by submitting various documents to prove claims.

“So there [are] lots and lots of ethical standards that are already in place.”

Actors emphasized that because of the stringent regulations, it would be difficult for companies to place untested nano F&FP products in the market. Some participants in industry and associations argue that there is “over regulation” with too many laws that are dictated by various agencies in each jurisdiction. For example, approval processes have to go through several layers from “regional to provincial to national and at each stage it might be blocked by a set of questions.” There is the federal body that provides strategic concepts; then the provincial laws in Canada that set their own laws; and then the municipalities that “want to do it their own way” and control the market.

Participants from organisations agree that various regulatory steps are needed to get new and innovative products into market, even though some of these products are already approved, exported and marketed in other OECD countries; for example, many of the health claims that have been universally accepted (e.g. Phytosterol) are still under review in Canada. Thus, the process for approval is extensively long and time-consuming, and in some cases can take up to 5-10 years for approvals, resulting in delays and hindrance to innovation. This was corroborated by a policy maker, who acknowledged that regulatory amendments for food (and drugs) can take very long.

Organisations point out that they are prepared to “walk away” from nanotechnologies because “regulations are too severe and the market too small” to invest in the time and effort in getting approvals as it is too strenuous on them to go through such “ponderous” processes. They highlighted the “onerous” and “cumbersome” procedures needed to get approvals on even
simple changes to packaging. For instance, if a company wanted to change the colour and move some wording around a previously-approved label, they would have to go back to CFIA in order to get it re-approved, even though the information or the material is not really changed. Hence incorporating a new technology, like nanotechnologies, would undergo even more stringent processes when it came to approvals.

Many actors believe that such stringent regulations can be “a big barrier” (UNI/SCI/28SEPT12/FF/CAN) and “dampen innovation” (ORG/RET/EMG/7SEPT12/FF) rather than encourage innovation.

“... we were not looking to cut corners at the expense of health and safety, but we are saying that 10 years to approve a product that’s approved in 2 or 3 dozen other countries around the world, first world countries, with robust frameworks, there’s something wrong and it’s something that we have to address in Canada... I do not think that this is viewed to be a country that’s open for investment along this space.” (NFP/ASSO/11SEPT12/FF/CAN)

Due to this, often the R&D of new technologies is taken out of the country either because it “affects the profit line” or to avoid “certain kinds of other barriers, for example safety legislation, etc.” (UNI/LAW/ETH/19SEPT12/FF/CAN). Moreover, applications for patents are also being made in regions outside of Canada, such as the U.S.A. and Asia, where the “whole entrepreneurial climate... is a lot easier” (ORG/SCI/SR/EMG/25&28SEPT12/TEL/CAN) and where regulations are less severe and “more friendly to business” (ORG/RET/EMG/7SEPT12/FF).

A government official in HC agrees that the process is “convoluted” and “things are held up”, creating inefficiencies within the regulatory system and “frustrations in industry” (GOV/S&T/IP&PRO/12JUN12/TEL) that feel it is not overly transparent. Another government official promoting nanotechnologies believes regulations in Canada are competent but “chaotic” as there is “not enough people, not enough dialogue, not enough responsibility for the issues” (GOV/PRO/ADV/18SEPT12/FF/CAN).
5.3.3 Actors participation in policy debates and discussions

In national policy debates on nanotechnologies, the Canadian government endeavours to have representation from various actor groups, including consumer representative groups and NGOs that are invited to participate and provide their perspectives on issues around nanomaterials. For example, before passing the Bill S-11, Safe Food for Canadians Act, various stakeholders from industry, universities, the CFIA, and other agencies, working in the N&N area, were invited by the Senate committee of the Parliament of Canada in August 2012 to discuss the impact of nanotechnology in Canadian forestry and agriculture. Various not-for-profit organisations in Canada also organise discussions around the implications, the possibilities, the opportunities and the challenges of nanotechnology in agriculture, food and the environment. The Canadian Farm Business Management Council and the Home Credit Canada regularly organise meetings with scientists who are “actually getting their hands dirty and doing stuff” (UNI/SCI/27SEPT12/FF/CAN) in order to get their inputs on these issues so that they can create more awareness among the farmers.

In the food sector, government officials organise a variety of food industry roundtables to discuss food safety and any new initiatives underway. For instance, the CFIA operates a Consumer Association Roundtable that is chaired and overseen by the Food Safety Officer. Involvement of the scientific community in such regulatory and policy debates is seen as essential for better communication and interactions between them and the regulators.

HC also has regular consultations with industry. For example, they were invited for consultations on regulatory changes for food additives that were recently incorporated. Feedback is often sought through external guidance documents that are disseminated through industry associations (e.g. Canadian Beverage Association) or the agency website. Many scientists from various food processing companies also sit in crown corporation boards, including federal and provincial agencies that look at funding research.

In a national conference on agri-foods in Ontario (a few years back), including policy-makers, NGOs and scientists, key players, from across Canada were invited to open up discussions on issues of nanotechnologies.
The Standards development committee also involve multiple stakeholder in deliberations on nanotechnologies for an “open and transparent means to develop useful documents.” (NFP/STAND/NANO/26SEPT12/FF/CAN). Besides scientists from the government, university and industry level, consumer representative groups and NGOs are also often invited to the ISO standards committee meetings. Occasionally scientists from the U.S. are also invited to the discussions on the risk assessments of nanotechnologies.

5.3.3.1 NGO participation in deliberations

The role of NGOs is considered important to the discussions and debate on new technologies, including nanotechnologies and they are often invited to discursions on such related issues because they want “that voice to be there” (GOV/POL/20SEPT12/FF/CAN). A number of consumer associations are also invited to give their thoughts around areas of major concerns that they believe want enhanced attention.

Some of the NGOS are global in their initiatives and are often involved in opening international debates on the safety of nanofood and agri-food products. However, the lack of funding for travel often hinder their ability to attend these meetings on a regular basis. Some CSOs/NGOs were also found to boycott these meetings. Under such circumstances, their opinions are often sourced from websites and media reports for inclusion in the discussions.

While the NGOs and consumer representative groups confirm that they are sought for their advice and feedback on issues by various government agencies on nanotechnologies, they point out that their proposals are usually discounted and they are often excluded from important debates where these are “dominated by industry” (CC/REP/29MAY12/TEL). A scientist serving on two of these committees confirmed that NGOs are not invited to such committees because, “They do not like the word ‘nano’” (UNI/SCI/27SEPT12/FF/CAN), but that government does listen to them.

As the only individual representative of their organisations, participants from CSOs/NGOs also expressed concern that their voices are often lost, drowned or ignored among such big corporate players that have huge presence in these meetings and promise to bring innovation and economic benefits to Canada. An industry lobbyist corroborated this fact that “NGO voices of complaint are largely ignored” (ASSO/PRO/8JUN12/TEL) as the government is more
interested in new technologies that bring economic benefits. Scientists point out that inputs from industry is “seriously considered by the government” (UNI/SCI/27SEPT12/FF/CAN) and they are given very high importance in such debates in order to understand their needs; and if they object, “it is taken very seriously” (UNI/SCI/6SEPT12/FF).

5.3.4 Addressing ELSI and EHS issues

5.3.4.1 Deliberations on safety issues of nanofood and packaging

Discussions and debates on the potential use and concerns of nanotechnologies in F&FP, have been minimal and almost absent in policy debates, according to policy-makers and scientists present in policy debates. Much of the discussions have centered on nanotechnologies benefits in other sectors, such as energy, and that on food has largely been given a backseat. According to a participant in the ISO/TC 229 standards committee, they “have not had any intense discussions specific to F&FP” though there is awareness that “it might be a potential application coming along” where standards need to be developed (NFP/STAND/NANO/26SEPT12/FF/CAN). Participants from industry associations too pointed out that nanotechnology is something they “just don’t hear much about” (ASSO/PRO/SR/PKT/24SEPT12/FF/CAN) though there might have been “a few stories here and there” (NFP/ASSO/11SEPT12/FF/CAN), because there is pressure to discuss and address other issues and hazardous chemicals, such as mineral migration, waste package reduction, BPA in food packaging, etc. Companies also tend to focus on waste diversion, sustainable packaging, recycling, and food safety during meetings. There are no “top line discussion[s]” on nanotechnologies in the F&FP industry “because people have no clue” (ASSO/PRO/SR/PKT/24SEPT12/FF/CAN).

An ethicist argues that discussions around environment and health issues of nanotechnologies, if any, are often “wasted” as they are “hijacked by the extremists” – NGOs - who are against nano or anything with the word ‘nano’ as they consider the technology to be “evil” (UNI/ADV/ETH/14SEPT12/FF/CAN).

A government official believes that such issues and debate “need some leadership” from the federal government that “should have taken a much stronger role with respect to this area” (GOV/PRO/ADV/18SEPT12/FF/CAN) and bring together people from different areas to
encourage more dialogue and networking on these aspects. According to the respondent, with no one talking about it, it becomes difficult to understand the position of regulators and the people. There is also an indication from an industry participant to form a “watchdog committee” (ORG/SCI/SR/EMG/25&28SEPT12/TEL/CAN) that can overlook such matters though they acknowledge that it is difficult to pinpoint the dangers that exist from nanotechnologies. A lawyer points out that nanotechnology is still “nebulous” and even if people get together to have “those discussions there isn’t necessarily anything concrete that they’re discussing” (UNI/LAW/ETH/19SEPT12/FF/CAN).

Some institutes help create awareness of such issues among industrial players by involving them in research and offering them free support. For companies “it’s a good image” as they are keen to make money and “don’t want their people – their workers and their client, they don’t want anybody to get hurt...” (GOV/INST/SR/ETH/6NOV12/CAN). However, an advocate of nanotechnologies from a government agency points out that while some companies directly approach them for help on issues of nanotechnologies, a majority, 90% of them are, however, unwilling to acknowledge using the technology in their products and shy away from any help freely offered to them.

Thus, NE3LS, created in 2010 by the Government of Québec, stemmed from discussions on the impacts of nanotechnologies at NanoQuébec. The aim was “to make everybody talk to each other” in order to be able to “better evaluate all the impacts of nanotechnology” (GOV/INST/SR/ETH/6NOV12/CAN).

5.3.4.2 Insufficient funds

While there were various reverberations of government support towards applied research among participants, there were many references by participants about not enough funds being directed towards, ELSI and EHS issues. Though some funding was available, these were for short periods of seven years, which according to scientists, is a very short time to assess the technology. Thus, while the “attention is there, but funding is lacking” (UNI/SCI/27SEPT12/FF/CAN) for safety issues of nanotechnologies. According to the participant, there are various safety measures in place for regulations of food, but more needs to be done in terms of finances and “the amount of attention that need to happen in this food nanotechnology area.” This is corroborated by an NGO, who points out that while Canada
already has a definition and “has taken some steps ahead of the U.S.” to attempt to understand nanotechnology “a bit better”, it still lacks investments towards safety issues and “there is still lot of growth” that needs to take place in Canada in order to make sure that the technologies that are produced are safe, efficient and “are done for the right reasons” (NGO/NANO/31MAY12/TEL/CAN). The participant maintains that an appropriate amount of money, into environmental, health and safety test research for nanomaterials needs to be undertaken.

A senior government official asserts that if the government wants a return on investment they would need “to speed things up” (GOV/INST/SR/ETH/6NOV12/CAN) with the industry too, and would need to take more responsibility to redirect funds from fundamental research to address concerns of nanotechnologies. The participant pointed out that it is also most unlikely that start-up firms that receive a start-up fund of CAN$2 million would invest CAN$ 200,000 in toxicology tests because unlike large firms, SMEs and start-up firms do not have the cash flow to do such research and so maybe the government would need to help some companies finance part of this work. Thus, there is consensus among various actor groups that funding for research by the government “should pay greater attention to certain areas that impacts on human health and safety” (GOV/PRO/ADV/18SEPT12/FF/CAN) so that they can address issues of nanotoxicity and create “safe passage of those material[s] to market and create some wealth for the society”.

5.3.4.3 Research on EHS & ELSI

The study found that, despite the lack of funding and deliberations on nanotoxicity in government, various institutes and universities, are carrying out research to address safety issues of nanotechnologies (see Appendix 14 for details on institutes funding EHS and ELSI research in Canada)

Not-for-profit organisations such as Nano BC, NanoQuébec, Nano Alberta, NE3LS, IRSST were identified as institutes that are actively encouraging and/or promoting the ‘responsible’ development of nanotechnologies through R&D in the EHS and ELSI areas. Government agencies, especially in Québec, are also involved in funding research to assess the safety of nanomaterials. According to a participant, the Québec government is conscious of the backlash
that occurred with GMO and so are being more cautious this time round to ensure that their investments in nanotechnology meet the safety standards needed for public acceptability.

While resources have been allocated to address various concerns surrounding nanomaterials, a participant from a civic group argues that many of the consumer concerns were still not addressed and “are being left off the agenda” (CC/REP/29MAY12/TEL/CAN).

5.3.4.4 Setting safety criteria for funding

According to scientists, funding for nano-based projects are allocated based on the ability to provide adequate steps for biosafety tests, where novel materials like nanomaterials are used. The proposal guidelines that are submitted for funding must include additional information in support of the tests that will be carried out to ensure safety of nanomaterials and should clearly outline “how [they] are going to handle this particular challenge.” (UNI/SCI/27SEPT12/FF/CAN). A scientist working on nano-packaging pointed out that when the proposal that was submitted by them for funding did not include biosafety information, they were asked to send in the details.

“And then we knew they are going to hit on biosafety because when we put together [the proposal, we] didn’t have enough information, so we kind of indicated that there will be biosafety issues which we will address in the full proposal.” (UNI/SCI/15OCT12/TEL)

It was also pointed out by a participant at a firm that earlier funding was easily available for projects where nanotechnologies were added in proposals but recent applications specifically ask for additional information on safety tests if the proposal entailed the use of nanotechnologies.

However, this study found that though these protocols were in place, funding agencies were not involved in checking the safety of the final research product, and it was left to the researchers to ensure safety of the research and product.

The release of the funds is also contingent on receiving the ethics board approval on research. Every institution in Canada that is eligible for agency funding is required to have a Research
Ethics Board (REB), properly constituted, as outlined in the Tri-Council Policy Statement (TCPS). There are various health and safety committees, such as the Animal Care Committee for animal testing and the Ethics Committee for human testing, at universities that do safety reviews (and not the government funders) to decide whether a research can be undertaken or not.

5.3.5 Labelling nano-based products

As consumers, consumer representative groups and governments around the world are calling for mandatory labelling of products incorporating nanomaterials, it was essential to get the views of various actors on labelling of nano F&FP products.

As stated in the introduction chapter, my interest in Canada began with a media coverage in 2009, which announced that Canada has become the first country to call for mandatory labelling of nanomaterials. However, this study found that though the initiative was being considered by the GoC at the time, it was a miscommunication on the part of a government official, which got picked up by the media. Canada has not, as yet, implemented mandatory labelling of nano-based products.

On the other hand, manufacturers/producers pointed out that labelling products as “non-nano” would also send out a wrong message to consumers who would perceive it as saying, “Oh, all the rest of it has nano in it, well nano can’t be good” (ORG/SCI/MAN/13SEPT12/FF/CAN) and nano products are unsafe, as it happened with GM foods. Either ways, it would erode customer confidence in nanomaterials.

According to a scientist, labelling products as ‘nano’ would create a negative impression as it would not be grounded in solid scientific support and would therefore do “more harm than good” (UNI/SCI & ADV/7JUN12/TEL). It would also confuse customers, especially as they lack “proper knowledge” (UNI/SCI/PGK/29SEPT12/FF/CAN) to make a selection between a nano product and a natural product on the shelf. Actors argued that consumers “are not equipped to make the decision” and will “right away... put up the shields” (UNI/SCI/PGK/29SEPT12/FF/CAN) when they see ‘nano’ on the packaging, and would instead look for a product with a ‘natural’ label. They pointed out that though consumers are highly educated they do not have sufficient understanding of the technology to make a
judgement. Thus, labelling would only provide information but would not educate consumers. Moreover, “they’ve got to want to listen” (UNI/SCI/F&P/27SEPT12/FF/CAN).

An ethicist argued that there is not enough evidence that shows that labelling is truly helping the public and giving everybody “every little piece of information is not helpful” (ORG/CNST/2JUL12/TEL) because then it may as well have everything on it.

A scientist emphasised that companies too would be unwilling to label products as ‘nano’ “because they would have less chance really to sell their food products” and if they are made to they would not want to work with it and “take it away immediately” (UNI/SCI/F&P/27SEPT12/FF/CAN).

An ethics lawyer perceives labelling as a “weak form of regulation” (UNI/LAW/ETH/19SEPT12/FF/CAN) that allows consumers to make informed choices and “either consent or not consent whatever is in the product” (UNI/LAW/ETH/19SEPT12/FF/CAN), though not everyone reads them. A second lawyer questioned the benefit of labelling and the value of putting every little bit of information on packaging.

However, civil society groups demanded the labelling of products incorporating nanotechnologies. An NGO argued that it would be “irresponsible” (NGO/NANO/31MAY12/TEL) not to label products especially if they are not going through a screening process. They emphasised that industry likes to “blindfold” consumers into selling products and so don’t want to label products because consumers would otherwise “not buy into the product” (NGO/NANO/31MAY12/TEL/CAN). Moreover, a participant from a consumer representative group pointed out that consumers have a right to know what is in the product and want labelling of such products. However, while participants from retail firms acknowledged that the consumer has a right to know what is in the product they questioned whether consumers were knowledgeable enough to understand nanotechnologies and whether it was worth risking their business by being open when it could create further uncertainty and negative repercussions.

Thus, none of the actor groups emphasised on labelling nanofood products (except NGOs), because they pointed out that nanomaterials in some products were present from time unknown.
5.3.6  Regulating at the border

Regulating nano products across borders is a challenge for regulators in Canada. Products, such as nutraceuticals and nano fertilizers, are easily available over the internet or imported across from the U.S. and thus difficult to monitor. One NGO pointed out that they were even able to order nanomaterials over the internet and received the package without “any regulatory processes involved” (NGO/NANO/6JUN12/TEL).

A senior science advisor agreed that monitoring products at the borders can be challenging because new technologies, such as nanotechnologies “really needs time to get into the system” and that can only be done when there is “mass market” (GOV/SR/ADV/SCN/1AUG12/CAN). Moreover, there aren’t “enough people to be able to monitor products coming into the country” (UNI/SCI & ADV/7JUN12/TEL) and the border agencies do not have the capability to identify nanomaterials in food even if they were asked to inspect goods because these would require advanced electron microscopes. The available capacity for inspection at CFIA and other agencies for details on government knowledge) for such nanomaterials entering the market too is limited.

A food regulator agreed that it is a challenge “to try and keep on top of every individual product that is out there” (GOV/FOOD/14MAY12/TEL). However, some participants believe that Asian countries like India, are slowly beginning to follow an approach that meets international standards and many of the food products sold in supermarkets in developed countries that have been imported from such countries, already follow safety regulations and protocols required by the system.

However, the Canadian government’s responsibility is national and they do not monitor companies beyond its borders. Thus, Canadian companies setting up shop in countries outside of Canada would follow the regulations set by the jurisdiction in which they operate and are not regulated by the Canadian government. A government official at a funding agency emphasised that the Canadian export companies are expected to “live up to Canadian standards” (GOV/FUN/POL/17SEPT12/FF/CAN) when they enter new markets, though that may vary. A nano ethicist pointed out that there is no agreement on a common definition on nanotechnologies at a global level, so enforcing any regulations for nano products across borders with different regulatory settings could turn out to be even more problematic,
especially in developing countries where the regulations are often “skipped” (UNI/ADV/ETH/14SEPT12/FF/CAN).

5.4 Responsibility/RI

In order to understand how the ‘responsible’ development of nanotechnologies for F&FP sectors is shaped by the normative framing of technology within each region, this section provides the findings of what ‘responsibility’ means to participating actors in Canada, their interpretation of what it is to be ‘responsible’ and who they consider is ‘responsible’ for the ‘responsible’ governance of nanotechnologies.

5.4.1 Perceptions of ‘responsibility’

The findings show a variation in the notions of ‘responsibility’ and RI among the participating actors. “Innovative products”, “health and safety”, “public acceptance”, “ethics”, “transparency”, “future impacts” and “standards and regulations” were some of the key phrases that appeared across perceptions of ‘responsibility’ and RI. Most participants were approving of innovation but cautioned using the technology without ensuring to some extent that it was safe for public health and environment.

Public acceptance and support was an important highlight among various actor groups in their perceptions of RI. They reasoned that without consumer acceptance, there was no market for products with emerging technologies like nanotechnology. Hence, part of ‘responsibility’ is to gain public acceptance by ensuring safety of products and creating products that brought consumer benefits.

“... most people don’t innovate unless there’s actually you know slight betterment or improvement that customers are gonna want... So responsible innovation I think at least in the early stages, there would be some idea that there be a market for it and there would be some acceptance of it.” (ASSO/PRO/8JUN12/TEL)

“Very important, because if it’s not accepted by public, there’s no need to develop product, it’s a very important to inform the [people] about nanotechnologies, to
educate them. This can only be done if we are sure that there are no risks, so it’s mandatory to acceptance of this product.” (NFP/PRO&OWN/NANO/15JUN12/TEL)

In order to address public concerns and acceptability of nanotechnologies, regulation/regulatory frameworks and standards were seen as important instruments in overseeing ‘responsibility’. Participants repeatedly referred to Canada’s robust system and regulatory guidelines that are provided to “spell out what you can and can't do” and to ensure “research does not harm people” (GOV/FUN/POL/17SEPT12/FF/CAN). Where these are not present participants believe “systems of governance” (UNI/ETH/30JUL12/TEL/CAN) should be set up, which may not be regulatory but are responsive to public concerns. Also, as part of ‘responsibility’ it is essential to ascertain whether the existing laws and regulations are sufficient to govern new technologies, and if they are not, then to “get them up to speed relatively quickly” (UNI/ADV/ETH/14SEPT12/FF/CAN).

According to a respondent working on standards, RI is about developing new ideas into commercialised products and during the process “addressing applicable standards” (NFP/STAND/NANO/26SEPT12/FF/CAN) that might be there and adapting them to cover anything new and different that nanotechnology brings. According to a participant from a not-for-profit organisation, RI is developing products and technologies that meet “ethical standards” (NFP/PRO/19NOV12/TEL/CAN) and the means to test it with the involvement of external groups. A government official in a funding agency believes that researchers and experts in Canada practice ‘responsibility’ by being conscious of the harm that can be caused due to the introduction of “inappropriate technologies” or “technologies that have consequences”, which have not been explored or tested, and by self-regulating or practicing through guidelines which are set at various levels of research to ensure safety of human beings (GOV/FUN/POL/17SEPT12/FF/CAN).

Almost all actor groups connected ‘responsibility’ and RI to ‘safety’ as a priority for human health and environment, involving ethical practices and consideration of the long term impact of their innovation. Thus, RI was perceived as considering the effects of the product through its entire lifecycle, right from the stage where it is created to the stage where it is disposed, including cost of the product, where it involves social responsibility to make the product accessible to everyone.
According to participants from firms and industry associations, ‘responsibility’ is about ensuring the safety of food.

“For us, no.1, it’s about ensuring that we have safe products in the market place...” (NFP/ASSO/11SEPT12/FF)

For firms, including manufacturers of food and nutraceutical products, “Safety is... way-way up there” ahead of such things as sustainability and environmental footprints, “and preeminent on everybody’s minds (ORG/RET/EMG/7SEPT12/FF/CAN. A participant from a retail firm also perceives ‘responsibility’ as ensuring that the food manufactured by them helps people “eat healthy food by providing them with healthy choices” (ORG/SCI/SR/EMG/25&28SEPT12/TEL/CAN). Thus the notion of ‘responsibility’ and RI is related to two critical factors - food safety (mainly) and nutrition.

“RI to us means... The first important thing is food safety... Other things that are important are sustainability which in our case would be packaging and... nutritional value of food...” (ORG/SCI/SR/EMG/25&28SEPT12/TEL/CAN)

“We are always concerned about the health, always, always whenever we feel something is not safe, people they don’t use it, they don’t buy it.” (ORG/REG/11SEPT12/FF/CAN)

A similar view was expressed by participants in the scientific community. To this actor group, ‘responsibility’ relates to product safety and a need to be conscious of the implications of the negative impacts that new technologies might bring on the environment or on humans and “wouldn’t deliberately harm a being or environment.” (UNI/SCI/F&P/27SEPT12/FF/CAN). It is about ensuring there are no new dangers associated with the technology, “whether intentionally or unintentionally” (GOV/SCI/13JUN12/TEL) and that if the technology does not work well, then “you know not to try that” (UNI/SCI/F&P/27SEPT12/FF/CAN). “Even if there is a question about the safety of the product or its long term effects” (UNI/SCI/6SEPT12/FF) then enough work needs to be done to ensure it is safe before going forward. According to a food scientist in a private firm, responsibility lies at the top of the pyramid “in the hands of those developing that technology” and it has to be “truthful” (ORG/SCI/MAN/13SEPT12/FF/CAN).
Similarly, in their interpretation, participants in government agencies related ‘responsibility’ to “a clear focus on ensuring safety” (GOV/ADV&LAW/NANO/25JUN12) and the mindfulness and intent of various actors to do research ‘responsibly’. Many participants in this group remarked that queries on RI is a “tough question” (GOV/ADV&LAW/NANO/25JUN12) and “a very difficult term” (GOV/PRO/ADV/18SEPT12/FF/CAN) to address and “not one that [they] have used or that is part of a policy” (GOV/FUN/ETH/POL/20SEPT12/FF/CAN). According to an official, RI is about considering all the “ramifications of using the technology” (GOV/INST/SR/13NOV12/CAN) and using the knowledge and best practices available at the time “to do the best at that time with consciousness” (GOV/S&T/IP&PRO/12JUN12/TEL) to mitigate the negative or harmful effects of innovation on human health and environment, while also being conscious of the fact that responsibility can never lead to “zero risk” (GOV/S&T/IP&PRO/12JUN12/TEL/CAN) or 100 per cent success at the end. Thus, it is about balancing benefits and risks from new technology “without incurring harm to others” (GOV/PRO/ADV/18SEPT12/FF/CAN) and is “ethical” (GOV/FUN/POL/17SEPT12/FF/CAN). According to a senior science advisor, RI is about researchers being self-aware of the benefits and detriments of their research, because it is not possible to regulate their work every step of the way.

However, a participant from an ethics institute pointed out that the problem with nanotechnology, in general, is that there is perhaps not enough data to support what would be ‘responsible’ development and so “innovation has to be in harmony with society” and include “responsible goals” that consider not only aspects of safety and sustainable development but also what impacts the product will have (GOV/INST/SR/ETH/6NOV12/CAN). It means that each player within their role “needs to consider the range of impact” (GOV/FOOD/14MAY12/TEL) and identify potential risks that using nano-ingredients or other additives in F&FP may have on the health and safety of consumers. A government official promoting nanotechnologies stressed that the mission of sharing information around health and safety, environment and ethical questions of nanotechnologies with various stakeholders was part of ‘responsibility’.

Some participants first sought to define their view on irresponsible innovation. A scientist stressed that to be responsible, one would need to consider what “irresponsible innovation” (UNI/SCI/24SEPT12/FF/CAN) is. Thus, if someone created and distributed products, which
could improve human health, but “don’t care” what about its safety aspects pertaining to health and environment after it completes its role, then that would be irresponsible innovation. For example, if innovation is deliberately targeted to making weapons much more effective or that could distribute anthrax much more effectively, that, according to a participant, would not be RI; it would be ‘irresponsible innovation’.

While the above notions of ‘responsibility’ focused on health and safety aspects of nanotechnologies, there were various references to economic development and betterment of society. Participants also related RI to the development of new and novel products for the improvement of society, expansion of markets and enhancement of the economy. According to a scientist in government, RI is about developing “innovative new bio products, bio processes, technologies and products” that are new, “green” and offers an advantage to the Canadian industry as well as the agricultural sector to “be ahead in the market place” (GOV/SCI/25MAY12/TEL). It is about creating economically cheap, and environmentally safe product with “a huge novelty embedded into it” that can benefit people (UNI/SCI/27SEPT12/FF/CAN). To a scientist involved in packaging, RI is about creating a biodegradable packaging for food, which would help industry “expand the market” (INST/SCI/8NOV12/FF/CAN). Another scientist working on packaging relates ‘responsibility’ to sustainability, not just to the environment, but also to the economy where the society can be prosperous and not live like “cavemen” (UNI/SCI/PKG/29SEPT12/FF/CAN). Interestingly, the perception of RI for a respondent in a packaging association, was about making money and meeting the “triple bottom line” i.e. the three “Ps” – people (the innovation should be safe and healthy for consumers), planet (it should be environmentally friendly) and profit (it should be able to bring financial benefits (ASSO/PRO/SR/PKT/24SEPT12/FF/CAN).

A lawyer pointed out that ‘responsibility’ requires recognising that there will be unforeseen and unintended consequences and owning up to it would be ‘responsible’ even though these are unforeseeable. According to the respondent, part of what becomes challenging about ‘responsibility’ in policy-making around nanotechnology is how to deal with unintended consequences. According to the participant, if these technologies have the potential devastation that many believe they have, then safeguards, such as the traditional precautionary principle need to be built.
Perceptions from NGOs and consumer representative groups were based around ‘responsibility’ of researchers and industry to ensure safety of new and innovative food products through enhanced and defined regulations by government, and transparency, where the public are kept informed of such emerging technologies in these products. If they are going to create something it is done such that “in no way hinders the health of this planet or the health of other people” (NGO/NANO/31MAY12/TEL) and the same amount of passion and dedication that is used in creating the product, goes into ensuring that it is safe. For a representative from a consumer group, RI entailed industry being aware of the implications and impacts of their products, not only on the health of the consumers but also the effects on the environment because there is “no clue what’s going to happen” (CC/REP/29MAY12/TEL) when these materials get into the landfill.

Taking a different perspective, a food scientist at a university, questioned the perception of RI relating to nano-based food products. With the example of non-healthy “sugary” foods and drinks like Coca Cola in the market, the participant pointed out that in contrast to these products, nano-based food products can provide healthier options of food, which can have more benefit for consumers than some of these other products that are already approved and in the marketplace. The participant points out that if the question of ‘responsibility’ arises, then it should also be adapted to other ‘non-healthy’ products in the market.

“I try to do my innovation that would lead to products that would improve the health as a micro nutrient. Hopefully by using hi tech structure agents, they don’t make it worse... Actually, this is the first time I hear anything related to RI, related to... food products. However, you may extend that into the creation of sodas, sugary drinks. There should be no Coca Cola if we want RI. People should not put out drinks that are 20% sugar because people are gonna get diabetic and obese. Or maybe we shouldn’t eat pastries because they’re really high in fat, we’re all gonna end up fat. So RI – if it’s gonna be adopted – should not be only given to nanotechnology but to the whole food manufacturing endeavour. We should not put unhealthy foods out, and that would cut out about 50% of the food products in the marketplace.” (UNI/SCI/28SEPT12/FF/CAN)
5.4.2 Who is responsible

The main challenge in the debate on nanotechnologies is ascertaining who among the various actors along the value chain is accountable and responsible for the governance of nano-based products and processes. This section investigates who the actors perceive is responsible for the governance of nanotechnologies in F&FP.

5.4.2.1 Notions of shared responsibility

This study found that various actors, including government officials, scientists, industry associations and NGOs, were in consensus that the ‘responsible’ development and governance of nanotechnologies is a “shared responsibility”, whereby everyone along the value chain has an important role to play to ensure that they are using nanotechnology “very wisely” (GOV/INST/SR/13NOV12/CAN) and the products are safe. For example, private sectors that wish to apply nanotechnologies have a “corporate responsibility” to ensure that they do their “due diligence” (NGO/NANO/6JUN12/TEL/CAN); scientists, that come up with “new phenomenon” (GOV/FOOD/14MAY12/TEL/CAN) contribute to ‘responsibility’ by “acquiring knowledge” (GOV/SCI/25MAY12/TEL/CAN) that can help ensure the safe use, disposal and consumption of these products; the “regulatory folks” and the “surveillance overseers”, are responsible to set strong policies and standards and look for potential hazards to protect the public (GOV/FOOD/14MAY12/TEL/CAN); manufacturers that integrate new applied technologies into production mechanisms “can’t think purely economically” (GOV/SCI/13JUN12/TEL), they are ‘responsible’ to ensure safety of their workers and products; the industry associations and organisations that are involved in supporting research are also responsible; the retailers have a ‘responsibility’ because they must be aware that there may be “a lot of ignorance” (UNI/ADV/ETH/14SEPT12/FF/CAN) by consumers with respect to what they are actually selling; those involved in communications and advertising are ‘responsible’ to ensure that messages going out to consumers are truthful and not misleading with respect to the nature and safety of products; civil society groups practice their ‘responsibility’ by representing the public and apprising them of issues; and there is ‘responsibility’ on the part of consumers and workers as well, to ensure that they have a knowledge of the benefits and limitations of these technologies.
“So I think all stakeholders that are involved in either developing and selling that product or in certifying that product is suitable for sale in Canada, have some share of the responsibility.” (GOV/SCI/13JUN12/TEL)

“Well I don’t think there is one that is accountable, I mean I think they work together in tandem, you know in order to establish and abide by the framework to ensure safety...” (GOV/S&T/IP&PRO/12JUN12/TEL)

“Everybody’s accountable... it’s all of them.” (NGO/NANO/6JUN12/TEL)

“I think everybody in the entire value chain needs to be responsible, everybody” (NFP/PRO/19NOV12/TEL/CAN)

“Everybody has a certain responsibility...” (UNI/ADV/ETH/14SEPT12/FF/CAN)

However, as this responsibility is passed on from one actor to another, that is from the researchers, to the producers to the manufacturers, the retailers, consumers, etc., it is “much diluted in terms of true understanding and the depth of knowledge” (ORG/SCI/MAN/13SEPT12/FF/CAN).

5.4.2.2 Responsibility of industry

While everyone within the food chain was considered to have a share of ‘responsibility’, various actors stressed that a “good chunk” (UNI/SCI/24SEPT12/FF/CAN) of the ‘responsibility’ lies with the industry – those that are manufacturing and applying nanotechnology to their products. The industry was seen to have greater ‘responsibility’ because it is the decision of the companies to prove whether a product is safe or not and “so they’re very conscious of that” and have “the capabilities to actually prove that”. Moreover, as pointed out by participants, companies are the ones that are “making the profit” (CC/REP/29MAY12/TEL), and “successful for a reason” (UNI/SCI/F&P/27SEPT12/FF/CAN) and are “the only people with the finances” (UNI/SCI/F&P/27SEPT12/FF/CAN) that can hire legal teams and expert scientists that can look at such safety aspects. However, in order to avoid a “conflict of interest” it is important for companies that want to market their products using such new and controversial technologies to carry out research and safety tests with
scientists in an independent laboratory. Because of the large surface area of nanomaterials, issues can also arise due to contaminants and may not necessarily be due to the presence of nanoparticles used in products. Thus, manufacturers have an added ‘responsibility’ to ensure that during manufacturing there are no contaminants. In packaging, nanomaterial producers, integrators and nano-packaging manufacturers are considered to be ‘responsible’ for the governance of nanotechnology, and “will have to deal with... any risk of contamination to the food.” (NFP/PRO&OWN/NANO/15JUN12/TEL).

According to a government official, whether it’s “a little company” or “a big company”, industry is still responsible for what they are putting in the product (GOV/ADV&LAW/NANO/25JUN12/TEL). A scientist from a firm too agreed that “…the responsibility lies with those who are going to apply it.” (ORG/SCI/MAN/13SEPT12/FF/CAN).

A CSO, while agreeing that industry “needs to be held accountable”, pointed out that the industry is not “conscious of their responsibility” because they have not taken the ‘responsibility’ to push for regulations or connect with consumers to “seek out the input from the public” (NGO/NANO/31MAY12/TEL). However, from a legal perspective, it was pointed out that the industry is both “causally and... morally” (UNI/LAW/ETH/19SEPT12/FF/CAN) ‘responsible’ for the development of nanotechnologies because they have made choices presuming that they know that there are certain risks and gone ahead anyways, especially without regulation. Considering that they have developed products in the absence of regulations, the industry would therefore be “legally liable” (GOV/ADV&LAW/NANO/25JUN12/TEL) for the safety of products in the absence of regulation.

5.4.2.3 Responsibility of government

Various actors pointed to legislative authorities, particularly Health Canada, that are paid tax to “represent the citizenry of the country” (UNI/SCI & ADV/7JUN12/TEL) as having the main responsibility to govern innovations, in particular the introduction of new technologies into the food chains. Many participants in organisations and the scientific community pointed out that the government has the main ‘responsibility’ because they are the final “jurist” (UNI/SCI & ADV/7JUN12/TEL) when it comes to “safety regulations” (UNI/SCI/27SEPT12/FF/CAN) of nanotechnologies because they have the ability to develop standard tests and put in some
legislation and “some rules to the game” (UNI/SCI/28SEPT12/FF/CAN). Moreover, regulatory bodies, according to them, are responsible for approving products before it is placed in the market, so they have the responsibility to govern what is put in the market.

A food scientist stressed that the government needs to give nanotechnologies more attention and there should be “a special consideration” for nanoscale objects or products whereby a “Nanotechnology Directorate” should be created under Health Canada (UNI/SCI/28SEPT12/FF/CAN).

Participants in organisations too agreed that it is the responsibility of the government to ensure public safety and since issues of nanotechnologies involves human health, the government should take the responsibility for the governance of nanotechnologies because (i) “people’s health is most certainly the responsibility of government.” (ORG/SCI/SR/EMG/25&28SEPT12/TEL/CAN), and (ii) all the products that are placed in the market are first registered with the government, and they “don’t approve anything even if there’s a little doubt” (ORG/REG/11SEPT12/FF/CAN).

Policy-makers acknowledge that there is responsibility on the part of the government in Canada in regulating nanomaterials but pointed out that private companies that wish to apply these new technologies need to do their “due diligence” (GOV/FOOD/14MAY12/TEL) in seeking out information that is essential for the preparation of submission to regulatory authorities when they are applying to use these new technologies. According to a respondent working on standards, enterprises, including small firms, need to ensure that they carry out all the tests with the information that is available to them, “even if there are no specific regulations yet” (NFP/STAND/NANO/26SEPT12/FF/CAN).

5.4.2.4 Dual responsibility of industry and government

Many actors argued that the industry or the government alone are not responsible to ensure the ‘responsible’ development and governance of nanotechnologies, but that the industry and government have a shared responsibility to ensure that products that are produced and marketed are safe. While the industry is considered as the main entity that is responsible to ensure that the product that they are placing in the market is safe because they are the ones that will reap the economic benefit of what they are doing and “driving it”, the government is the entity that
has the responsibility to support this by “regulating the process” based on what they know is needed to regulate within a country or beyond (UNI/SCI/12OCT12/TEL/CAN). A scientist points out that industry are quick to “jump into the bandwagon” and “do things irresponsibly”, without really understanding what its impact will be on human being or environment (UNI/SCI/12OCT12/TEL/CAN). Thus, the government “should be a little more responsible” (GOV/SR/PRO/7NOV12/CAN) to ensure that companies developing novel products declare everything and have everything.

5.4.2.5 Responsibility of scientists

Though the responsibility of the safety of products rests on the people who apply it to their products, responsibility is also found to depend on the “credibility and the accuracy” (ORG/SCI/MAN/13SEPT12/FF/CAN) of the researchers. Scientists often work with industry, whether at university or within firms and thus have a role in bringing forward issues to the attention of federal labs, regulators and industry associations. Thus, various participants from the scientist community acknowledged that the responsibility for the governance of nanotechnologies is also theirs as they have to ensure that whatever leaves their labs is safe, especially in the initial stages of development of nanotechnologies. According to a scientist, if “there is an element of safety at risk, then it should not even go to the consumer” (UNI/SCI/6SEPT12/FF).

5.4.2.6 Responsibility of consumers

Consumers were also seen as “co-players” (GOV/FOOD/14MAY12/TEL/CAN) in the governance of nanotechnologies in the F&FP, in ensuring that they become more educated in order to be able to make their own assessments, and “stand up for themselves” (NGO/NANO/31MAY12/TEL) by asking enough questions about the safety of the innovative products before accepting and buying them. It was considered everyone’s responsibility to educate the general public about nanotechnologies, through workshops and talks organised by such entities as the industry associations. However, in the absence of sufficient data on nanotechnology, there was a question on what is it that they would be educated on.
5.4.2.7 Responsibility of CSOs/NGOs

The NGOs are also seen as important intermediaries in responsibility pertaining to the safe and ‘responsible’ development of nanotechnologies.

Majority of the actors believe that NGOS are an interest group “that needs to be heard.” (NFP/STAND/NANO/26SEPT12/FF/CAN). According to them, NGOs represent the general public and bring forth debates and issues that might have escaped government and policy-makers’ attention. Participants also stressed that it is important that different views expressed by NGOs are considered, because they are not concerned about controversy and are free to take an independent, unbiased stance on issues “as opposed to trying to be more objective or less controversial” (GOV/PRO/ADV/18SEPT12/FF/CAN).

In government, NGOs are seen as “vocal” (GOV/SCI/13JUN12/TEL) entities that are “curious or conscious or concerned” (GOV/S&T/IP&PRO/12JUN12/TEL) and have very important perspectives on new technologies, which need to be heard. NGOs are also seen as playing an influential role in the way standards, policy and regulation are evolved by bringing to the attention of policy-makers issues that sometimes skip their attention. According to a government official there is only so much that the government can fund or investigate directly with the resources that it has, and so they need NGOs to “step up and help fill knowledge gaps and provide expert input on all the various issues at hand” and inform government of the various issues associated with nanotechnology (GOV/SCI/13JUN12/TEL). However, a senior advisor for science believes that NGOs do not have any role to play in the governance of nanotechnologies and that their only responsibility is “more education and practically bringing information to consumers” (GOV/SR/ADV/SCN/1AUG12/CAN).

A scientist, on the other hand, agreed that though NGOs may be skewed towards a negative perception of nanotechnologies, they have a “very influential voice” (GOV/SCI/13JUN12/TEL) and could provide useful feedback that could be incorporated in their research and used in future policy and regulation, and product acceptability. However, another scientist pointed out that some NGOs “may be part of a negative perception of nanotechnology” (UNI/SCI&ADV/4JULY12/TEL) and may not realise that there could be a lot of benefits in nanotechnologies because their opinions are based on “emotional reaction, not necessarily an answer from scientific knowledge” (INST/SCI/8NOV12/FF/CAN). Thus, it is
important that everyone should work with NGOs, listen and consider their opinion, and “when they are interested and reasonable” (GOV/SCI/25MAY12/TEL), their point of view should be incorporated into their work.

A lawyer, described the role of an NGO as “a social ombudsperson” because they are able to bring issues into the limelight that puts pressure on an entity, particularly in such situations where there is no clear regulatory structure and “obvious laws”. (UNI/LAW/ETH/19SEPT12/FF/CAN).

Participants from an industry association had very critical views about NGOs and considered them to be “extremists” (ASSO/PRO/SR/PKT/24SEPT12/FF/CAN) and detrimental to the development and application of innovative technologies.

“I think they should go back to the caves that they lived in, put the rocks over the front of the caves… We have very little time or respect for them, because we find that most of them don’t have good solutions or good ideas. They just want to stop progress in general, most of them are anti-tech, same one as we see, anti-GM crops, anti a whole bunch of things. But they have very few workable solutions for feeding the world so we tend to discount them very quickly. And that is true… It’s possible if they were actually open-minded and wanted to listen, but the ones that we’ve dealt with are so close-minded, and their minds are made up. It’s actually a waste of our time to engage them to a large degree.” (ASSO/PRO/8JUN12/TEL)

Participants from retail firms, too did not see the NGOs as influencers of innovation and nanotech development because NGOs “are always anti-emerging technologies” (ORG/REG/11SEPT12/FF/CAN) that often range on one side from those who are “anti-manufacturer and confrontational to those who may be somewhat ambivalent” (ORG/RET/EMG/7SEPT12/FF) about new technologies and “make arguments that are not science-based, that are based on emotion or any other agenda” and thus are given “far too much credibility” (ORG/MAN/STGY/GM/26SEPT12/TEL/CAN).

Participants from CSOs/NGOs, however, insisted that they are not against innovation but saw themselves as caretakers of the public with a very important voice. They considered it their ‘responsibility’ as playing an important role in educating public on risks of nanotechnologies,
while “encouraging responsibility with the technology” (NGO/NANO/31MAY12/TEL/CAN), regulation and transparent dialogue, both, nationally and internationally. The participants also pointed out that they felt “morally obliged [and] ethically obliged” to call for the moratorium and to “try to get the governments to pay attention to it.” (NGO/NANO/6JUN12/TEL/CAN).

A consumer group has also been actively trying to bring the issues of nanotechnology and regulations forward in the Canadian parliament on a regular basis for a couple of years, and have approached MPs to discuss the issues. They are also active in putting forward proposals for labelling at the ISO technical committee concerning labelling. An NGO is also pushing to establish a convention at the UN that can assess and provide global transparency and oversight to the introduction of new technologies such as nanotechnologies, though a participant did not “think that the UN is going to have the clout to do much more than provide an early warning system.” (NGO/NANO/6JUN12/TEL). They believe that such initiatives even then would not be adequate, and hence the group is actively working with their partners to establish their own laboratories for technology assessment, for assessing such emerging technologies as nanotechnologies.

“So that we can kind of put some pressure on governments to hold them to a certain standard at least and they’ll always know that there’s another bar that’s sort of analysing these things besides themselves.” (NGO/NANO/6JUN12/TEL)

Despite calls by NGOs for a moratorium of nanotechnology R&D, participants pointed out that the debate on biotechnology is seen to be much more controversial and ongoing. According to a policy maker, nanotechnology has not caught on as much yet but points out that “it can be difficult to deal with a [NGO] group” (GOV/POL/20SEPT12/FF/CAN).

5.4.2.8 Responsibility of celebrities

Some participants pointed out that it is essential to be cautious in the way that nanotechnologies are marketed. While some people market it as “rocket science stuff” in pursuit of profit, others create a “nano fear monger” and either of these extremes can be “pathetically catastrophic” (UNI/ADV/ETH/14SEPT12/FF/CAN).

It is also important to consider who is delivering the message, and how people receive it. Participants believe that celebrity opinion can have devastating effects on how
nanotechnologies are perceived in society as they are better able to sway public opinion than the media. A scientist points out that Prince Charles “started lighting these cauldron[s]” (UNI/SCI/F&P/27SEPT12/FF/CAN) years ago, and everyone ever since then have got on board saying that nanotechnology is bad. Taking the example of celebrities Jamie Oliver and Dr. Oz, participants pointed out that if they stand up and say, “Nanotechnology is so bad”, people will listen to them, and not the normal media.

“And if Oprah Winfrey says anything, it’s like God spoke or something like that.” (UNI/SCI/F&P/27SEPT12/FF/CAN)

According to a participant even people that are selling the product are “ignorant” and not aware of the potential harm that nanotechnology may cause to health and environment.

5.5 R&D of nanotechnologies

This study found that R&D in nanofood and packaging and agri-food products are at an early prototype stage in universities and have the potential to go into market soon (See Appendix 15 for further details on projects). However, scientists are finding it difficult to move to an advanced stage due to lack of funds to study the environmental and ecological impacts of new nanotech products. Moreover, organisations are very cautious of taking the first step to use nanotechnologies in their products for fear of not only public backlash, but potential safety issues that are linked to nanotechnologies (See Figure 12).

5.5.1 Industry fear

While there is much interest in the potential benefits and use of nanotechnology within the food sector, the industry is afraid of using nanotechnologies in their products, “because of all the problem[s] that might arise from the use of [this] technology (GOV/INST/SR/ETH/6NOV12/CAN).

Various actor groups pointed out that though the industry is trying to advance and do research, since innovation is essential to their business, they “do their work underground” (NFP/ASSO/11SEPT12/FF) and “keep it under wraps” (NFP/STAND/NANO/26SEPT12/FF/CAN) because of concerns from public and fear of sudden
backlash from NGOs. As pointed out by participants, large food ingredient suppliers such as Danisco, CPG (consumer packaged goods) companies and large multinationals like Nestle, Coca Cola and DuPont are all known to conduct some activities around nanotechnology but "maybe keeping a little bit close" (UNI/LAW/ETH/19SEPT12/FF/CAN) in terms of what they say and what they do not say about nanotechnologies and its associated risks, and thus lack transparency.

However, in defence of the companies, a food scientist points out that companies do not ignore the presence of nanomaterials in products such as packaging but instead put it aside because “what the public don’t know won’t hurt them” (UNI/SCI/F&P/27SEPT12/FF/CAN), especially if it is beneficial for them.

“And so what I’m trying to make is that sometimes the consumer doesn’t have to know, because it gets misled, and as long as it’s giving benefit, and not deceiving them – which it isn’t in this case.” (UNI/SCI/F&P/27SEPT12/FF/CAN)

Furthermore, participants pointed out that companies are reluctant to talk about nanotechnologies because Canada had very good success with GM foods, but when the debates on GM foods exploded in Europe some years ago, it seriously affected Canada’s export of food to Europe because GM crops and any GM-related crops or GM non-certified crops were banned from Europe for several years. This caused significant losses to the Canadian farming industry because Europe was one of their major markets. Thus, “it’s not to the advantage of Canadian food producers to stimulate those discussion” (GOV/FUN/POL/17SEPT12/FF/CAN). Furthermore, with various recalls on products occurring in the food industry globally, “It starts to put the brakes on things” (NFP/PRO&OWN/NANO/15JUN12/TEL) like nanotechnology because the industry gets nervous.

Participants maintain that people are also ‘nanophobic’ and confused about the technology, and so even if companies were given a nano-based packaging product that could increase the shelf life of food, “the company would rather stay away from that” (UNI/SCI/PKG/29SEPT12/FF/CAN) and they “would not be the first” to test it in the market because they would be fearful of “a big rebellion against their organisation.” (GOV/S&T/IP&PRO/12JUN12/TEL), which could cause reputational damage.
The industry does not see a lot of incentive because the federal government “has not really been overly engaged in setting standards on the issues.” (NFP/ASSO/11SEPT12/FF). They are seeking clear guidelines because “they don’t like a situation which is uncertain and where there are potential liabilities down the road that they can’t foresee” (GOV/PRO/ADV/18SEPT12/FF/CAN). Thus, until there are clear-cut guidelines from the government and consumer acceptability of nanotechnology, “big players are zipping up” (UNI/SCI/27SEPT12/FF/CAN).

A food scientist maintains that they have tried working with Canadian companies but the companies had a very cautious attitude when it came to nanotechnologies, and thus researchers had to turn to international partners.

“I wish I would be working more with Canadian industries. Most of the industry I work [with] is international, not national. And that’s not from lack of trying.” (UNI/SCI/28SEPT12/FF/CAN)

A senior official from a government institute acknowledges that “it was very hard to interest the industry” because industry “are afraid of a bad perception of the public”. However, the participant points out that the industry are the cause for the negativity because they keep everything underground and the perception would be much better if there were “less secrets” (GOV/SR/PRO/7NOV12/CAN).

Participants from firms concur that it would be a challenge for them to market nano products without regulation and public acceptance. Food safety is a paramount issue for food manufacturers and retailers and while they see ample benefits for applying nanotechnologies in their products and “super excited” (ORG/SCI/MAN/13SEPT12/FF/CAN) about the technology, they are “scared to death” (ORG/SCI/MAN/13SEPT12/FF/CAN) to take any steps immediately because “the media may get hold of it and call it something that it’s not” (ORG/SCI/MAN/13SEPT12/FF/CAN) and then “tear the entire company down”. Thus, until they can ensure that people become “sufficiently comfortable” with the technology and the companies are able “to make a credible judgement” on the risks, there will be “trepidation” among organisations to use it (ORG/RET/EMG/7SEPT12/FF). Furthermore, these firms questioned whether consumers were knowledgeable enough to understand nanotechnologies.
and whether it was worth risking their business by being open when it could create further uncertainty and negative repercussions.

“You know on one hand you say well if I’m using nanomaterials, I need to tell the consumer. Well if the consumer can't understand what they’re reading or what they’re seeing, then I’m introducing a level of risk that’s unacceptable. So I’m not prepared to do that. So, you know, I would continue with my brand as it, because I don’t have anything on that package that introduces a question mark... I don’t think we would have any interest going down that route...” (ORG/RET/EMG/7SEPT12/FF)

This fear was evident during my visit to Canada for field study whereby almost all the organisations doing research in nanotechnology that were approached for an interview were unwilling to disclose or talk about it.

Figure 12: Reasons why industry is reluctant to use nanotechnologies in F&FP

Source: Author
5.5.2 Collaborative projects with Indian researchers

The findings show that India is on the radar for research collaborations by various institutes and government agencies as it is seen as a region where the benefits of nanotechnology can be immediately utilised in the rural sector. According to a science advisor, a large amount of the S&T funds has been diverted for collaborative projects in India because there is no language barrier and “obviously [it] seems to be a good market for Canada” to bring their expertise in different aspects of technology over to Canada.

The flexible regulatory environment in India is also an attraction to organisations and institutions wanting to sell products or do nanotech research. A participant from an organisation sees developing countries (like India) as a potential market for nano-based products because they are not required to modify their products unlike other developed nations, which have various protocols that need to be met.

“India is at an early stage of development in many respects, and I think in early stages of development it’s a much more entrepreneurial environment… One because that’s where the growth is, but secondly that’s where the opportunity is in terms of accepting, being able to promote, being able to sell some of the things that we already make without modification.” (ORG/RET/EMG/7SEPT12/FF)

An ethicist at a university points out that India already has “a leg up” with regards to nano medical advances, and if they saw a benefit for nanotechnology use for their own people, especially the poor, then they would see an opportunity to apply their “nanotechnological prowess” for F&FP (UNI/ADV/ETH/14SEPT12/FF/CAN). However, according to the participant, it may mean that in order to extend such benefits to its people or pursue profits, developing countries might go to the extent of ignoring regulatory protocols to achieve their goals. This would result in developing countries creating products much faster than the developed world and the developed world could be “hampered precisely by its own respect of the law and of regulations” (UNI/ADV/ETH/14SEPT12/FF/CAN). Moreover, the participant argues that there is usually a North-South divide where people in the developing world are used as “instruments” or “tools” to experiment on and to test products, where researchers in the developed world identify “some token scientist from India” to collaborate with and “pacify” them with carrots of “good papers” and “prestige” to carry out research.
The easy availability of technical skills is also an attraction. One of the main challenges identified by scientists working on nanotechnologies was the unavailability of qualified researchers. A university scientist working on FP points out that recruiting people with the right skill sets “is sometimes quite challenging” because many undergraduate students in Canada prefer to go and work for industry. Thus, scientists working on nanotechnologies are having to recruit talent from countries like India to make up the shortfall.

India’s open innovation culture also drives researchers to collaborate on projects. There are various nano-based collaborative projects underway between Canada and India. Discussions are underway by researchers at the Carleton University for collaboration with an organisation in India for a ‘smart fertilizer’ project. At the time of the interview the Canadian group was seeking funding from the Gates Foundation for funding that would enable them to pursue research in the area. The University of Alberta is also working on nanoscale projects for water purification in collaboration with Indian researchers to provide clean water to rural regions in Canada and India. Such projects are only “the tip of the iceberg” (GOV/FUN/POL/17SEPT12/FF/CAN) as pointed out by a government official at a funding agency. According to a food scientist, India is much more dynamic and understands that technology can help. They are not afraid to imbibe new technologies and “don’t care if it’s nanotechnology or not” (UNI/SCI/28SEPT12/FF/CAN). They are more interested in the benefits, and if the cost structure is right, they adopt it.

“And India is very well known for being very accepting of high technology in any market. Maybe it’s out of need that they need to innovate to be able to win. So but I find those cultures very different from here.” (UNI/SCI/28SEPT12/FF/CAN)

Some scientists view such innovations in nanotechnologies to help in the economic development of societies in these regions and also share knowledge and skills. According to them emerging technologies such as nanotechnologies can have major impacts and should be developed to solve critical problems in society, such as food and in agriculture, that have been prevalent in societies around the world for decades. A scientist in a food processing firm stresses that Canada is very conscious of the need to “do some good to those populations” in developing countries but at the same time make some money for companies.
“Canada, you probably know, feels a very great responsibility to health, to feed the hungry world in the future.” (ORG/SCI/SR/EMG/25&28SEPT12/TEL/CAN)

As part of its commitment to help communities in the developing world find solutions to social, economic, and environmental issues, while increasing their scientific and technological skills, in 1970 Canada set up a funding body, the International Development Research Center (IDRC) to support innovation that could help address the needs of such developing countries.

“The objects of the Centre are to initiate, encourage, support and conduct research into the problems of the developing regions of the world and into the means for applying and adapting scientific, technical and other knowledge to the economic and social advancement of those regions.” (IDRC Act, IDRC website)

One of such initiative was The Mango Project (as I call it), a nano-packaging project for prolonging the shelf life of mangoes. Further detail has been provided in the section below.

5.5.2.1 The Mango Project

In 2011, IDRC, together with the Canadian International Development Agency (CIDA) under the Canadian International Food Security Research Fund (CIFSRF), which was set up to fund projects on nutrition and food safety in developing countries, approved $2.5 million to fund research and development of a new packaging solution that will help extend the shelf-life of mangoes in India. The Mango Project was initiated to help small farmers enhance the shelf life of mangoes and therefore reduce income losses due to lack of post-harvest storage facilities. The project was selected through strict competition and was based on its ability to help small farmers cut income losses, while providing a solution that would be mutually beneficial for both India and Canada.

The Canada-India Mango Project brings together three institutes, located in three different regions – The University of Guelph in Canada, the Tamil Nadu Agricultural University (TNAU) in Coimbatore, India, and the Industrial Technology Institute in Sri Lanka - and two

55 CIDA is currently under proposed plans to be merged with the Department of Foreign Affairs and International Trade of Canada
technologies - a nano-film developed in TNAU by a doctoral student using nano-clay, and the hexanal formulation, which is developed by the University of Guelph. Hence together with the expertise of the team in the University of Guelph and the TNAU, the teams are working on creating a nano-film for packaging that can be used to extend the shelf life of mangoes.

The project highlights well-managed collaboration across two regions. “There’s no stepping on toes of each other” (UNI/SCI/6SEPT12/FF/CAN) as roles are allocated to various actors across the two settings based on their respective scientific and technological skills. In India there are six groups that oversee various activities – the Nano team, the Horticulture team, the Pathology team, the Technology team, the Social team and the Biosafety team. These groups work collaboratively with the scientists and research groups in Canada, reporting back regularly the results of their findings and discussing further tests and solutions that need to be undertaken. Thus, the project involves various actor groups that work together in a collaborative setting and is seen as a solution to address societal grand challenges (in this case alleviating poverty and hunger due to income losses by farmers), and for economic development. A funding criteria set by IDRC incentivises transnational collaborations between researchers based in regions that have different notions of ‘responsibility’ embedded in them. The responsibilities are mapped through technical and scientific development capabilities of the University of Guelph and the TNAU, where the hexanal formulation is carried out at the University of Guelph and the nano-film is developed in India. The project is worked out in such a way that the final solution will be extended to other fruits and vegetables in Canada and India, where a similar solution is needed to extend the shelf life of tomatoes, apples, oranges, peaches and plums, thus meeting other needs.

The project is interesting because it involves various actors across transnational settings. The project involves intermediary actors such as NGOs (e.g. the Mysore Resettlement and Development Agency) and growers’ associations (Mango Growers Association) that are actively involved in identifying small and medium farmers and working with them to understand their income losses and what benefits this new technology could bring to them. As intermediaries between the project researchers and the farmers their participation has helped appease any resistance from farmers in carrying out field (hexanal) tests without hindrances, thus avoiding a repeat of the GM saga.
According to a scientist on this project the responsibility of biosafety tests rests on the Indian partners where the nano-film is being developed. India has the necessary instrumentation and scientific skills to carry out the tests quickly, without having to wait in queues for using such facilities as is the case in Canada. However, in the absence of existing globally harmonized standards/protocols for biosafety tests for nanomaterials, these tests are conducted through mutual dialogues and agreements between Canada and India and by trained scientists in India (rather than trained technicians in Canada) which makes collaborating and communicating across transnational regions between scientists easier with similar backgrounds and knowledge. Moreover, sanctioning of funding by IDRC was based on the criterion that necessary biosafety protocols and tests are to be carried out, and should meet Canadian standards and approval by the committee represented by expert scientists; thus transferring Canada’s high standards to a region with potentially low standards of regulation. Conditions of governance is also set through regular reporting and dialogues between the various actors every six months, whereby the respective Universities are required to submit a report to IDRC on the latest developments and progress on the project.

5.6 Conclusions

In this section, I will offer a short summary of the findings/analysis and their relevance in the governance of nanotechnologies in my first case, Canada. I endeavour to establish Canada’s unique model in the governance of nano-based products in the F&FP sectors. In Canada the State is seen to play a key role in the ‘responsible’ R&D of nanotechnologies. This has been illustrated through five distinctive avenues in the following section.

5.6.1 Summary of findings and analysis: Case of Canada

As globalisation of innovation is creating new markets and opportunities for emerging technologies like nanotechnologies, and attention to the ‘responsible’ development of nanotechnologies is being given more attention in international policy debates, this research found a unique model in Canada where the State is seen to play a pro-active role in shaping processes of ‘responsible’ development of nanotechnologies. Canada has the same issues of regulating nanomaterials as are faced by most other jurisdictions around the world. As with most jurisdictions, Canada is struggling with ‘how do we regulate’ such materials as nanomaterials, especially in F&FP, which directly affects human health and environment. This
study found that Canada’s model for governing the R&D and future commercialisation of nanotechnologies in F&FP is carried out through five unique avenues:

i. **Encouraging and promoting domestic R&D and commercialisation at public institutions and through public-private partnerships:** The State in Canada plays an active role in the promotion and development of nanotechnologies as they see potentials for enhanced industrial competitiveness, economic growth, and societal benefits for Canada. Domestic R&D and international collaborations are encouraged through support given to universities, organisations and industry groups across its provinces. While there are no national strategies for nanotechnologies in Canada, the provincial governments, with the support of the federal government, are creating a hub for nanoresearch within different provinces. Financial support by way of funds and grants are also made available to universities for research. Industry participation is encouraged by way of match funding, either through cash or kind. This has encouraged organisations to support nanotechnology research in areas of nanofood and packaging and agri-food products.

ii. **Focus on the ‘responsible’ development of nanotechnologies:** Canada has established various programmes by making available funds that encourage focus on the ‘responsible’ development of nanotechnologies by supporting wider governance measures which will in future enable introduction of nanomaterials and products into Canadian as well as international markets. These programs include research on EHS, ELSI and toxicity of nanomaterials. These programs are carried out in a number of institutes in Canada, especially in the provinces of Québec and Alberta.

iii. **Regulating through existing stringent policies and legislations for novel F&FP products, and through the introduction of new standards and policies:** Canada’s existing regulation for F&FP products are seen to be very stringent, where approval processes for novel F&FP are long, taking up to 10 years, which prevent certain novel products entering markets too soon. The State has also established new policies, standards and regulations (through bilateral collaborative initiatives and participation in international regulatory committees) that would in future monitor and mediate the
import of nano-goods and materials entering its domestic markets through its porous borders, whether from emerging markets or developed nations such as the U.S.

iv. *Involvement of citizens’ groups in Canada’s policy debates:* The State also ensures that various stakeholders are invited and included early on in Canada’s policy debates on nanotechnologies. These stakeholders cover actors with varied roles and responsibilities to ensure a range of views are incorporated in policy debates.

v. *Developing transnational research networks in emerging countries:* Canada is building a network of international projects across emerging markets such as India. The formation of these transnational techno-scientific alliances is enabling Canada to establish research links in nanotechnologies and thereby influence the R&D of nano-products (e.g. in India) by offering the prospect of future export of products to Canada and/or collaborations in the development and commercialisation of nano-products with Canadian firms. Indirectly, these initiatives influence how emerging markets approach R&D of nanotechnologies, and aim to establish new markets for nanotechnologies.

5.6.2 Connecting to Chapters 6 & 7

In this chapter, I summarised the main findings from the analysed data gathered from the first of my two cases, Canada, an OECD country. Using these findings, I will investigate my two research sub-questions (See Appendix 19 for research sub-questions that are linked to the findings in Canada).

In the following chapter, I will present the findings of my second case, India, a non-OECD economy and similarly investigate my two research sub-questions using the findings.

I will then discuss the commonalities and differences in the two regions/cases, using the findings and analysis of both these cases, while answering the research questions in Chapter 7.
CHAPTER 6

FINDINGS & ANALYSIS: THE CASE OF INDIA

6.1 Introduction

6.1.1 Connection to previous chapters

In the previous chapter, I provided detailed findings and analysis for the first case of this research. The findings in Chapter 5 led to five unique avenues of ‘responsible’ governance practices within Canada and provided an understanding of actors’ notions of ‘responsibility’/responsible innovation as perceived through their lens. It also provided an in-depth understanding of the regulatory regime in Canada and actors perception of regulation for nanotechnologies in F&FP. The findings in Canada showed a unique governance structure in Canada where the State is seen to play a pro-active role in shaping processes of ‘responsible’ development of nanotechnologies through stringent legislations, discursive democracy and distributed responsibilities. These findings provided a base from which to contrast an OECD country with a non-OECD country.

6.1.2 Aim of this chapter

This chapter aims to understand the notions of ‘responsibility’ as perceived by various actors in the nanotech food chain in India, the second case of my study. In particular, it will focus on regulation and the governance of nanotechnologies in India; notions of ‘responsibility’/RI as perceived by different actors in the nanotech F&FP sectors; and the subsequent shaping of markets of nanotechnologies in an emerging country like India.

The chapter analyses the existing regulatory regime and the challenges faced by various actors in the absence of regulation. The findings capture notions of ‘responsibility’/RI, which is based around the perception that there are greater challenges and issues that need to be addressed in India – such as poverty, providing clean drinking water, increasing income for farmers – and these challenges can be overcome through the use of such emerging technologies like nanotechnologies. It argues that responsibility pertaining to nanotechnologies in India is
shaped by perceptions of various actors that believe that responsible innovation is about socio-economic development. The chapter reveals that in India there is greater focus on the benefits of nanotechnologies rather than on risks. While focusing on the benefits of nanotechnologies, as perceived by actors in India, this chapter also highlights evidence of various ongoing ad hoc projects on nanosafety and strong collaborations between developed countries and India, with shared responsibilities and expertise on issues of nanosafety across diverse settings of regulation. It narrates actor perceptions of ‘safe’ and ‘natural’ products. It identifies a unique model adopted by scientists and entrepreneurs to appease public backlash based on past GMO experiences, where NGOs or extension agencies are used to promote nanotechnologies and educate farmers.

Perspectives from twenty-six participants with diverse roles were gathered through in-depth, exploratory interviews by telephone, Skype and email. These included actors from industry (small and large firms), government (policy-makers and officials at government-led institutions), scientists (from firms and government institutions) and intermediary organisations (such as industry associations, NGOs, extension agencies). Table 3 in Chapter 4 and Table 17 in Appendix 18, provides further details of the roles of actors and their organisations, respectively.

As with the previous chapter, the direct quotes of actors have been cited under inverted commas in italics. Due to the limit on word count of a thesis, I have once again used phrases from the direct quotes of interviewees in sentences to illustrate the difference in perceptions of a varied group of actors. In order to maintain participants’ anonymity, each interviewee was given a code (explained in detail in Chapter 4, section 4.5.3.). For example, ORG/MGT/INNO/31JUL13/TEL/IND, refers to a participant from an organisation (ORG), based in India (IND), is at a management-level (MGT) and is involved in innovation (INNO) within the organisation, was interviewed on 31 July, 2013 (31JUL13) by telephone (TEL). Words/phrases in square brackets used within these quotes refer to absent words added by the author.

6.1.3 Chapter sections

This chapter is divided into six main sections: Section 6.2 provides an understanding of the situation of nanotechnologies in India, including the support and funding available from the
GoI, social acceptability of this new technology, debates and challenges (faced by small firms) that are prevalent in the region. It also outlines the strategies used to promote nanotechnologies in India, using celebrity endorsement and NGOs. This section also discusses the challenges in promoting nanotechnologies, and how safety of nanotechnology is currently being addressed in the region. Section 6.3 provides an outline of the regulatory frameworks in India, with a focus on F&FP and a discussion on the challenges faced by smaller firms and their call for regulation. Section 6.4 offers an analysis of the notions of ‘responsibility’ and responsible innovation as perceived by the participants. Section 6.5 provides details on some of the existing R&D projects of nanotechnologies being carried out in public and private organisations, including universities and firms (both large and small) in F&FP (including agriculture, fishery and poultry, which form part of the food chain) and international collaborations. Finally, section 6.6 concludes with a summary of the unique findings through five scenarios.

6.2 Supporting nanotechnologies R&D in India

The following section aims to provide an understanding of the trends and spends on F&FPN in India. The section highlights the existing support of government towards funding of research projects of nanotechnologies at public institutes, while also investigating the social acceptability of new and emerging technologies.

6.2.1 India’s interest in nanotechnologies

In India, all actors, including government officials, scientists, NGO, industry associations and firms were synonymous in their perspectives on new and emerging technologies. According to them, new and emerging technologies, such as nanotechnologies, can provide revolutionary opportunities for economic and social benefit and was seen as a means to solve the country’s societal grand challenges, especially in agriculture. It is seen by scientists as a ‘smart technology’ that can replace “traditional agriculture” and improve the lives of the farmers by enhancing and utilising natural resources and “doing things differently or different things.” (DIR/NGO/16SEPT13/TEL/IND). Because of concerns on rising populations, situations of depleting natural resources and the challenges of climate change, nanotechnology is seen as a complement to existing technologies where the potentials can be explored to help overcome these problems and create a sustainable supply chain for the society, especially for those at the bottom of the pyramid. Furthermore, as a major producer of diverse food commodities,
nanotechnologies are being utilised in India for “long storage and right storage” (GOV/SR/19SEPT13/TEL/IND). While one participant from an organisation pointed out that the use of nanotechnologies per se “is not a big deal” (ORG/MGT/INNO/31JUL13/TEL/IND) and the fact that nanotechnology is used is secondary to the issue of consumer concerns, a government official sees it as a means of “showcasing that India can do it and it can also excel into this area of research.” (GOV/SCI/14SEPT13/TEL/IND). According to a senior government official from an R&D institute, this is a “decade of innovation” for India and “nanotechnology is a major focus in India” (GOV/SR/19SEPT13/TEL/IND). Thus, the “Government is certainly promoting research and development.” (UNI/SCI/29JUL13/TEL/IND).

6.2.2 Funding nano-based projects

6.2.2.1 Public sector funding

According to participants, nanoscience and technology is relatively well-funded in India. Funding is easily available to scientists in government-led research institutes with innovative ideas. Medium to large funding is available for fundamental work which is expected to lead to innovative outputs, for example, projects for food packaging. There was consensus among majority of participants that “there is a lot of support from the government.” (GOV/SCI/11SEPT13/TEL/IND) towards infrastructure and project funding. Many scientists pointed out that the government is “keen to spend on this new technology” (GOV/SCI/14SEPT13/TEL/IND) and thus funding is “available easily” (GOV/SCI/21AUG13/TEL/IND) and “if somebody has a good project, funding it is never a problem.” (UNI/SCI/16AUG/TEL/IND), including in areas of F&FP, though there is no guarantee that projects can be further funded in its second phase. This is corroborated by participants from private firms. According to a participant from a large firm, the investment in R&D by the Indian Government for new and emerging technologies exceeds that invested by private sectors. Furthermore, companies receive a 200% tax relief, and “there’s tonnes of funds available for joint projects (ORG/MGT/INNO/31JUL13/TEL/IND). A participant from a company promoting nanotechnologies too confirms that the support from government “is fantastic” and they are “full[y] involved” (ORG/PRO/23JUL&2AUG13/TEL/IND).
However, while there is easy availability of funding towards R&D for government institutes and universities, some scientists pointed out that there is no strategy to take it forward to industry or market and so they have to take their own initiative to look for a “taker” (UNI/SCI/16AUG/TEL/IND) in private firms or industry.

Conversely, participants from small companies spoke of the struggle in finding funds for R&D in nanotechnologies because much of the government funding was being allocated to “the big people” and “old”/experienced (ORG/SR/SCI/9AUG12/SKP/IND) researchers at government-led institutes/universities, because it was expected of companies to put in their own funding. Smaller organisations and innovators pointed out that they are “like a single man army” (ORG/SR/SCI/9AUG12/SKP/IND) who were putting in their own resources towards projects because even the banks were unwilling to give them a loan for a technology that is still at a very nascent stage, and no one has faith in their products. Entrepreneurs without valid academic qualifications are further side-lined from receiving any funding from any government because the credibility of their research is questioned and “they will ask thousand and one things” (ORG/SR/NANO/8AUG13/TEL/IND).

This was corroborated by a scientist in a government institute that “funding is quite easy” (GOV/SCI/18SEPT13/TEL/IND) for those in government-led institutes compared to firms.

“They all have their hands…they’re saying they are tied, ‘no-no if it’s a private company you will have to fund it’ and all that. And when you’re in starting time you don’t have much resources and you’re doing on your own, doing the testing trials and all that. It’s little depressing…” (ORG/SR/NANO/8AUG13/TEL/IND)

6.2.2.2 International support

Interviews with scientists found that large numbers of nanotech projects in F&FP are also funded through international collaborations. Most projects that are being funded by such international institutions are required to contribute to the sustainable transformation of Indian agriculture in order to relieve poverty and improve income for poor farmers. In 2007, the National Academy of Agricultural Research Management (NAARM), a GoI institution that focuses on agricultural issues in India, received World Bank funding towards a project, called
India National Agricultural Innovation Project, which assesses the potential of nanotechnology in the agricultural food chain in India.

Similarly, in 2011, the IDRC, a funding agency in Canada, together with CIDA under the CIFSRF, approved $2.5 million to fund R&D of a nano-packaging film at TNAU. The project was funded on the understanding that it will help poor farmers reduce income losses due to lack of post-harvest storage facilities by extending the shelf-life of mangoes grown by them. (A more detailed narrative of this project has already been presented in Chapter 5, section 5.5.2.1)

The emphasis in both these projects were to accelerate partnership with all stakeholders, including public research institutes, farmers, NGOs and industry and increase income of poor farmers.

### 6.2.3 Strategies for promoting nanotechnologies

Various strategies are used to promote use of nano-based products to farmers and industry. These are marketed through various marketing vehicles, including word-of-mouth, through industry lobbyists, print media, radio and television advertisements, distributors, workshops, etc.

#### 6.2.3.1 Celebrity endorsements, organisational reputations and technology perceptions

According to participants, over the years, various organisations have been selling products labelled as ‘nano’, and “every Tom, Dick and Harry wants to use it whether they understand it or not.” (GOV/SCI/EHS/6SEPT3/TEL/IND). Certain big firms in India are using the term ‘nano’ as a way of promoting their “commercial presence in a positive way” (GOV/POL&SCI/19JUN12/TEL/IND) because it is considered trendy. Moreover, as university scientists pointed out, the word ‘nano’ in India is used as a buzzword on products (such as nano car by Tata), even though it may not have any nanomaterials, as it’s considered “useful” as a term to claim things, or is just “fashionable” to use because it “pays rich dividend” (UNI/SCI/16AUG/TEL/IND). Companies see it as an “incentive” to use in inciting consumers to believe that it is “revolutionary” (UNI/SCI/FD/29JUL13/TEL/IND).
According to an IIT scientist, Indian organisations understand very little about nanotechnologies but do the technology transfers solely based on the reputation of institutes and universities. “so they say that there’s a lot of basis of this.” (UNI/SCI/20AUG13/TEL/IND). However, some other participants, pointed out that industry do have a good understanding of the safety issues pertaining to nanotechnologies.

According to some participants, companies such as Luxor, are using celebrities like well-known Indian celebrities like actor, Amitabh Bachchan, in advertisements to sway consumers into buying nano-products (see Appendix 3).

for advertisement). Because these products are being endorsed by renowned celebrities and sold by reputable conglomerates, “people will definitely go for it” (UNI/SCI/20AUG13/TEL/IND) and thus few people will question its safety.

Furthermore, with greater challenges of poverty and clean drinking water facing the Indian subcontinent, the appearance of nano goods or nano-labelled goods in India are often accepted by the Indian public as a means of technology fulfilling certain societal needs, as pointed out by different actors. If technologies like nanotechnology are able to solve some of the pressing societal problems, then people are willing to accept it, and don’t question the technology, especially if it is sold by well-known and credible organisations. According to a scientist:

“…the rural people are very actually happy that somebody is trying to solve their problems.” (UNI/SCI/FD/29JUL13/TEL/IND)

For example, silver nano-based water filters are commonly sold in India and there is no public backlash on these products in urban nor rural regions, according to some scientists and participants from organisations. Companies that launched these water filters in the market did not face any challenges pertaining to the use of new and emerging technologies like nanotechnologies, because as one company pointed out the use of silver as a material that kills bacteria has been known in Indian Ayurveda (a form of traditional medicine) for centuries. Moreover, faced with a choice of buying “something that takes care of all the bacteria or all the virus, all the cysts and the physical and chemical issues” (ORG/MGT/INNO/31JUL13/TEL/IND) as against what is already there - dirty water - the public are more welcoming of the former.
However, while it is easy to promote new technologies in urban regions through advertisements and celebrity endorsements, in rural areas “few champions”, such as NGOs, are used where the awareness and education levels are low.

6.2.3.2 Unique role of NGOs in appeasing societal backlash

The study found that various organisations and research institutes (in a range of sectors) work with NGOs to support and implement new technologies in rural regions in India. This includes large conglomerates that have established their own not-for-profit units for rural development to work with NGOs to propagate new technologies across platforms.

Various research institutes and organisations are also working with NGOs to propagate nanotechnologies in rural regions. Since nanotechnology is very new in India and “people have no clue what it is” (ORG/FD/31JUL12/TEL/IND), NGOs are seen to play a crucial role in creating awareness and promoting the technology. NGOs are used by both organisations and scientists to educate people in rural areas on how the technology works, “So locals help locals.” (ORG/FD/31JUL12/TEL/IND).

Currently, scientists at TNAU are working with an NGO that have strong connections with farmers, to assist them in carrying out field tests and in educating farmers on nanotechnologies. CSIR, which developed a terracotta-based water filter candle incorporating nanomaterials to provide clean, drinking water to villagers in rural areas, also engaged NGOs in various activities (including training) at the time of launching their product. Thus, NGOs are also being used to “create awareness and take the product to the right places” (ORG/PRO/23JUL&2AUG13/TEL/IND).

NGOs in India also work through Krishi Vigyan Kendras (KVK), which are agricultural extension centers or science centers mostly operated by the ICAR and some by NGOs. Present in each district, it is used to facilitate new technologies and train farmers in collaboration with research institutes and universities.

While NGOs are not very often invited to meetings and policy discussions on nanotechnologies, a participant in an association pointed out that “you have to keep good NGOs
in the loop” (ASSO/SR/INNO/26JUL13/TEL/IND) to ensure new technology “reaches the poorest of the poor” (UNI/SCI/15OCT12/TEL/IND).

Some scientists, industry lobbyists and policy-makers recognise NGOs as important delivery agents and partners because of their ability to take research from lab to field, to the poor farmers. A policy-maker pointed out that they are keen to avoid a repeat of the issues with biotechnology and GMO and they see NGOs as a means of delivering new and inventive technologies to rural regions, especially in agriculture where extension agencies can be used to connect scientists with the farmers. A university scientist also pointed out that many a times a lot of developments remain in the lab or in the industry and do not reach the common people; thus these NGOs use a community mobilisation method to work with “progressive farmers” (DIR/NGO/16SEPT13/TEL/IND) in rural regions and get small farmers together to try a new technology that would benefit them financially. This aspect is corroborated by a participant from an NGO, who pointed out that farmers are “not going to experiment with the technology merely because it’s new.” (DIR/NGO/16SEPT13/TEL/IND) and so it is essential to keep the farmers interested in the technology on the grounds that such a technology will increase his income.

Moreover, “every NGO has its different working system” (ORG/FD/AGRI/9AUG12/TEL/IND). While “there are some good NGOs, [and] there are some bad NGOs” (UNI/SCI/16AUG/TEL/IND), the ‘good NGOs’ are used as a “bridge” to connect various stakeholders, such as to connect a farmer to a university professor, scientist or a government official, and help “channelize” (UNI/SCI/EHS/17SEPT13/TEL/IND) products to farmers. Furthermore, these NGOs also bring the problems faced by the farmers to the scientists who can develop “a realistic product so that it will be useful to the farmers” (UNI/SCI/16AUG/TEL/IND).

However, a policy-maker was wary of using NGOs, stressing that NGOs do not understand the science behind nanotechnologies and most of them were against emerging technologies, due to the recent controversies on GM foods, and thus should not be given an important role. Various scientists had contrary views, and pointed out that people nowadays are very educated and thus NGOs too understand “high technology” (GOV/SR/19SEPT13/TEL/IND), which has made it easier for scientists to “explain the technology or make them learn the technology”
so that they can pass on the information to other stakeholders. Various scientists maintained that NGOs are “working for the safety of the people” (GOV/SCI/21AUG13/TEL/IND) and want to ensure that all new products are safe. They are “very smart people” (GOV/INST/SCI/TOX/2AUG13/TEL/IND) and often request to see safety certifications; and if they are satisfied with the evidence provided to them on safety, and the usefulness of products, then they play a key role in propagating the technology to society, including those in rural regions.

According to a scientist from a small firm, the uncontrolled use of nanomaterial by people will never stop because of the “greed of their business” and there is a danger that people will try to sell products without carrying out any testing. Under such circumstances NGOs are seen to be more proactive than the government to keep a check on such entities and “control the uncontrolled use of the nanomaterial” by stopping people from carrying out “filthy practices or the illegal practices” (ORG/SR/SCI/9AUG12/SKP/IND). However, while another participant agrees that NGOs are social activists that keep the interests of consumers in mind and are “a voice from the sort of a third pillar of society” (ORG/MGT/INNO/31JUL13/TEL/IND), a manufacturer did not concur that “there’s anything special they need to do for nanotechnology.” (ORG/MGT/INNO/31JUL13/TEL/IND). A participant at a food safety certification firm pointed out that while NGOs play a key role in getting food to the poor, there is always a doubt on how safe the food is, because the Food Safety Act focuses on “ensuring that the food reaches the people, rather than safe food reaches the people” (NFP/SR/FS/25SEPT13/IND).

Debates on nanosafety

The study found that debates around safety of nanotechnologies were limited and, if any, largely focused on applications for socio-economic development. Deliberations are government constituted and government managed and centre around storage of food, enhancement of shelf life of food, fruits and vegetables and safety of food. According to one university scientist/start-up company founder, there is no serious debate about nanosafety in India either because products with nanoparticles have been around for many years (such as in Ayurveda) or because there are no nano products around. Moreover, according to the participant, there are much more serious issues to discuss and worry about, such as
contamination of ground water and soil, among others, which are created by traditional misuse or inappropriate use of industrial technology than what might be brought in by nanotechnology. A participant from an organisation that promotes nanotechnologies too concurred that the issues of nanotechnologies “has not come to India” and that the participant has never heard any person saying, “okay nanotechnology will have an effect, that’s why I’m not going to market it” (ORG/PRO/23JUL&2AUG13/TEL/IND).

6.2.5 Challenges in promoting nanotechnologies

6.2.5.1 Fears from past controversies

Some participants believe that the GMO experience has brought forth fears surrounding the issue of safety of new and emerging technologies. Thus, farmers too are cautious and wary of using new technologies in agriculture. Participants are fearful that there may be resistance from farmers, similar to GMOs because 70% of the Indian population depend on agriculture. Hence, people are “really-really cautious” (UNI/SCI/15OCT12/TEL/IND). An NGO points out that nano-based products are promoted in rural regions based on the benefits it can provide to poor farmers to increase his income, otherwise there would be no interest in it.

“We’ll have to keep the farmer interested in the technology on the ground that such a technology will increase his income. He’s not going to experiment with the technology merely because it’s new.” (DIR/NGO/16SEPT13/TEL/IND)

Government officials too are very aware of the past controversies of GM/biotechnology and are concerned about the safety issues of nanotechnologies. There appeared a combined willingness by government officials to ensure that similar mistakes are avoided and efforts are in place for nanotechnology risk assessments through communication and biosafety tests so that “people are not alarmed by the word nanotechnology” (UNI/SCI/15OCT12/TEL/IND).
However, scientists believe that lessons have been learnt from GMO. Moreover, field tests for GM foods are not permitted and the same protocol is being followed as a “biosafety protocol” for nanotechnologies.\textsuperscript{56} As one scientist put it:

“...this as a scientist we are responsible...” (UNI/SCI/EHS/17SEPT13/TEL/IND)

6.2.5.2 Absence of regulations

Various participants pointed out that in the absence of regulations, there is no “recognition of the technology” (GOV/SCI/21AUG13/TEL/IND) and people don’t have “easy faith” (ORG/SR/SCI/9 AUG12/SKP/IND) in the technology and thus are wary of using them. Furthermore, farmers are unwilling to test products from unknown, small and new firms. Thus, various smaller firms are looking to sell their products to larger firms or farmers, because they “are willing to understand the potential of nanotechnologies more than smaller companies...” (ORG/FD/31JUL12/TEL/IND) and can also afford to buy the nano-based products. Hence, ORG1, a start-up firm that is just over a year old, is in discussions with Eureka Forbes, a consumer durable company, also manufacturing nano-filters.

6.2.5.3 Adopting new technologies

Participants point out that it is also difficult to change the psychology of farmers. Those that have been using chemical fertilisers for over forty years, are unwilling to try new technologies and “people are showing their reluctance to have [to] adapt” as they were “a little scared at the time to use new models and new chemicals.” (ORG/SR/SCI/9 AUG12/SKP/IND). As another participant in a small firm pointed out, it took forty years for farmers to accept chemical fertilizers and likewise it will take at least ten years before nano-products are accepted and incorporated by them. According to the participant, well-established and educated farmers that are interested in increasing their crop yields, are much more likely to be interested in new technologies. Another small firm (ORG3) too faced many challenges getting their technology accepted by smaller farmers that were using chemical fertilizers. The company then approached bigger farmers with 50-100 acres of land that were more willing to try the products.

\textsuperscript{56} However, as outlined later in his chapter, various field tests are already being carried out.
Some participants compared the Green Revolution of India with nanotechnologies, which involved the modernisation of farming techniques by using fertilizers and pesticides, leading to increased agricultural production in India in the 60s. According to participants, the negative consequences from the use of pesticides and fertilizers are only now known and a similar situation is likely to occur for nanotechnologies when the consequences can only be known years hereafter.

6.2.5.4 Issues of taxation

The study also uncovered various other challenges in the agricultural sector, such as issues of taxation as was faced by an organisation selling nano-based agri-products. According to the participant, tax laws in India dictate that products that fall under agriculture are taxable at 5%. Anything else would fall under 12.5% VAT. The challenge for companies selling nano products in agriculture is that nanotechnologies, as of yet, does not fall under any category for taxation. Hence, if the companies were to use 12.5% VAT when selling the products, it would be extremely expensive for farmers to buy the product and they would opt for a product or chemical fertilizer that was under the agriculture category where they would be taxed only 5% VAT. However, the participant also pointed out that if the government does cut down tax on nano products, they would not benefit much from it as the market is not big enough for nano products yet.

6.2.5.5 Resistance from ‘big fishes’

Smaller firms had additional challenges. As a small and new organisation, they do not have the financial backing for commercialisation or “great advertisement” (ORG/SR/SCI/9 AUG12/SKP/IND). They are also unable to collaborate with larger firms that are already well-established with a big share in the market, which are difficult to penetrate by smaller firms. According to a participant from an organisation, there is also resistance from fertilizer lobbyists because some farmers began buying the nano-based solutions for their crops and stopped use of fertilizers. This issue was also reiterated by another organisation, ORG2, that “big fishes are already into the market” and by the time the products reach the farmers, it will be displaced (ORG/SR/SCI/9 AUG12/SKP/IND). They are “waiting for the right time to launch” their product in the market. Thus, they are looking for a “linker”, a marketing firm, to help market their product so that they are able to concentrate on R&D. A third organisation too avoided
“high pressure selling” (ORG/SR/NANO/8AUG13/TEL/IND) or large markets, and faced similar challenges selling their product as people were wary of the new technology and reluctant to do trials.

6.2.5.6 Issues of technology transfer

The study also found that smaller companies and university scientists were facing difficulties in marketing the nano-products after it is developed, because there were no “takers” for the product after it is developed and thus “there is a certain amount of frustration” (UNI/SCI/FD/29JUL13/TEL/IND). Products that are developed through government funding are not only short term, 3-5 years, but also does not have an exclusivity right to the technology for organisations unless they “foot the bill” (UNI/SCI/FD/29JUL13/TEL/IND) by contributing towards IP expenses and other resources. Thus, competitive organisations are not quite interested in a product that is not exclusively licensed to them. Moreover, government “cannot keep funding these projects... forever” and thus do not get involved in commercialisation of products as it is left to the scientists to promote it to the private sector. Faced by these challenges, a university scientist has had to set up a start-up company in order to be able to find buyers for the product because the university usually does not deal with “productisation of [their] technology”. (UNI/SCI/FD/29JUL13/TEL/IND). A government official, who is aware of such issues in getting a partner or buyer, pointed out that people don’t understand nanotechnologies and at times the “product may not be rightly understood by the industry or it may be ahead of the time” (GOV/SR/19SEPT13/TEL/IND). A scientist from industry indicated that a market needs to be created because there isn’t a “ready market” (ORG/SR/SCI/9 AUG12/SKP/IND) for nanotechnologies yet. However, another scientist from university questioned whether industry would be ready to handle large productions of nanomaterials when it came to commercialisation (UNI/SCI/20AUG13/TEL/IND). One small firm received an order for three tons of a nano pesticide formulation but they were unable to deliver such a huge quantity of the formulation.

6.2.5.7 Border control

The study also found that organisations faced various challenges when importing or exporting nanomaterials. It was learnt that nanomaterials are being imported from other countries into India for R&D purposes. Nano additives are being imported through polymers containing...
additives. Nano fillers are also imported for R&D purposes from the U.S. and Japan and “sometime[s] there are lot of restriction[s] also to bring it” (UNI/SCI/16AUG/TEL/IND), especially from Japan as scientists are required to answer a lot of questions as to the purpose of use. According to a participant from a small firm, even mangoes exported by them to Japan are often subjected to stringent tests by the Japanese regulatory authorities.

A start-up organisation that faced problems importing nanomaterials at the Indian Customs stressed that the officials “don’t have any idea about what’s going on” (ORG/FD/31JUL12/TEL/IND) and wonder if the materials are hazardous and were sometimes suspicious that they might be smuggling in something that was contraband.

Some government officials agreed that it is a huge challenge and there is also difficulty in monitoring what comes into the country as India is a huge country with many ports. Checking complete batches of food products can be a daunting task, and they believe that there are nano F&FP products in the market that have been imported without their knowledge.

When asked if firms faced any problems exporting their nanomaterials to countries outside India, the founder of a small firm confirmed that he exports nanosilver under the silver category without problems because it is approved as an anti-bacterial and thus requires no additional documentation.

As a member of International Federation of Organic Agriculture Movement (IFOAM), a German Board, ORG3 also tried exporting its nano-based products to farmers in Poland, Australia, Malaysia, and Africa, but faced huge roadblocks at Customs. According to the participant, documents certifying the safety of products exported from India are often not accepted at international borders that carry out their own tests. Moreover, an HS Code (or Homogenous Code) is often required when exporting products from one country to another. Products that are certified Plant Growth Promoters (PGP) and Plant Growth Regulators (PGR)\(^57\) have HS codes set by the Universal Governing Body and can be exported. However, as nano-based products do not have HS codes, ORG3’s product often fail to meet the required regulatory standards in these countries. The company then exported its products to Poland

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\(^{57}\) Such certifications help to ensure that the ecosystem is not damaged when agricultural products are exported from one country to another.
using a different route by submitting a purchase order and letter from the farmer buying the product, who agreed to take responsibility for any damages the product may cause to his land. This way, the product was only tested for standard hazardous materials at international Customs.

While the export of ready-to-eat food products is not controlled by the government, the study found that export of agro commodities from India is controlled by the government. This is to avoid countries rejecting export consignments from India because of the presence of pesticide residues as it had happened in the past. Food (including fruits such as mangoes) that is being exported is often sent to independent food certification bodies by government agencies like the Agricultural and Processed Food Products Export Development Authority (APEDA) for testing.

Most interviewed government officials were unaware of various nano F&FP products in the market and believed that a focused research on food applications is still at “rudimentary stage” (NFP/SCI/GOVT/1AUG13/EMAIL/IND) and thus a contingency plan was not yet needed. While patents and publications are used to assess the ongoing R&D of nanotechnologies in F&FP outside of those funded directly by the government, government officials acknowledge that it is very difficult to keep a track of products that have been commercialised because of the absence of authentic data. For example, according to a promoter of nanotechnologies some products have been imported from other developed countries. Nano-silver anti-bacterial coatings, which have been imported from Germany are currently being tested at various supermarkets in India. Available in the form of a spray, they are being tested in restaurants, bottling and food processing plants, food stores and hospitals for anti-bacterial and anti-odour purposes. It is also being applied to the floors/yards of chicken hatcheries to kill red mite. An airline in India is also using these nanosilver coatings on food trays as an anti-microbial. However, the study found that regulators were unaware of these products in the market.

6.2.6 Addressing issues of safety

There is general awareness of the issues surrounding nanotechnologies and “there is a thinking about it” (UNI/SCI/16AUG/TEL/IND) that the safety issues need to be addressed. A university scientist pointed out that all scientists these days are aware of the issues surrounding nanotechnologies and thus carry out various tests to test for toxicity. Thus, researchers in India
do realise that they need to be cautious about nanotechnologies but at the same time there is not “much of a worrisome today”, and “having knowledge is a more realistic assessment of the situation and that’s happening.” (UNI/SCI/16AUG/TEL/IND).

However, a founder of a small firm pointed out that while there is awareness about nanotoxicity and “it does make noise” (ORG/FD/31JUL12/TEL/IND), it is not significant enough to actually make a difference and covers only 5% of the people working on nanotechnologies. Another participant from an organisation too emphasised being more caution with regards to concerns associated with nanotechnology because people are getting more aware of environment and health issues surrounding them.

Investments in nanotechnologies are often diverted to making innovative products rather than doing toxicology tests, though according to an organisation and a government official, “there are positive indications that this would be one major area where investments would be made.” (GOV/POL&SCI/19JUN12/TEL/IND; ORG/FD/31JUL12/TEL/IND)

Furthermore, some scientists and organisations are undertaking nanotoxicity tests in order to be able to meet demands set by developed countries that are setting stringent criteria for safety tests in collaborative projects. For example, it was found that sanctioning of funding by IDRC for the collaborative nano-packaging project between the UoG in Canada and the TNAU in India (refer The Mango Project in Chapter 5, section 5.5.2.1) was based on the criterion that necessary biosafety protocols and tests are to be carried out, and should meet Canadian standards and approval by the committee represented by expert scientists.

Similarly, the Central Institute for Research on Cotton Technology’s (CIRCOT) nanocellulose-based nanocomposites and fillers for packaging received much interest from international organisations in Sweden and France. However, the researchers faced some issues taking the product to market for food packaging purposes, and is currently working to satisfy some regulatory norms related to ISO standards for nanotechnologies. As part of their endeavour to meet safety requirements, toxicology tests to ascertain safety of nanocellulose, including microbial toxicity and cell toxicity tests, are being conducted at the IITR in Lucknow.

While there are no strategies in place for nanotoxicology, there are some efforts underway to try and understand how nanotechnology impacts health and environment. Various government-
led institutions, are working on ad hoc nanotoxicity projects that entail this requirement. These initiatives are either funded by the Central Government or by the institute or university where the research is being carried out. The IIT, India Institute of Sciences (IISc) in Bangalore, Centre for Cellular and Molecular Biology (CCMB) in Hyderabad and the CFTRI in Mysore, are some institutes that are studying safety and toxicity of nanotechnologies for health and environment. According to a University scientist, even though the government has not taken any major initiative, there are people at various institutes that have taken the lead to test safety of nanomaterials, such as leakage from nano-packaging materials into food. However, it hasn’t as yet been taken up extensively nor “government is announcing that there is a fund available and let us study this” (UNI/SCI/20AUG13/TEL/IND). There are also no contingency plans or a system in place, as pointed out by a government official (GOV/SR/19SEPT13/TEL/IND) in case of a major mishap.

Foods containing novel materials are often sent for testing to the referral laboratory of the GoI, CFTRI. However, according to a participant from a food certification firm, while CFTRI carries out numerous research on food technologies, they are not commercially oriented and thus “they don’t do much of commercial testing” (NFP/SR/FS/25SEPT13/IND). The Fermentation Technology and Bioengineering Department of CFTRI, has worked on a collaborative project with the Swiss Federal Institute of Technology (EPFL), Switzerland, which involved pesticide detection using nanoparticles. CSIR is currently working on evolving a specification process for nano products and framing guidelines for safe handling of nanomaterials, not only in research laboratories but also in occupational settings and in food and food-related items. The institute is also developing new methods of toxicity as risk assessment.

At IITR in Lucknow, various tests are being carried out to assess toxicity of nanotechnologies for human health and environment using cell lines, mice, rats and guinea pigs. For environmental studies, paramecium and drosophila are used. Nanomaterials are often sent to IITR by government-led universities such as IIT, because they have advance technical set-ups to test for toxicity. However according to a scientist from IITR, they “haven’t received anything from the industry so far as the product is concerned for safety evaluation of the nanomaterials” (GOV/INST/SCI/TOX/2AUG13/TEL/IND).
India is working on guidelines for safe handling of nanomaterials at the work place. The IITR has already developed a guideline for occupational health and safety of workers handling nanomaterials in the laboratories (not industry), which has been submitted to the DBT and currently under review. According to one of the scientists interviewed, while very few developed countries have such a guideline for handling of nanomaterials in the lab, this issue is “being seriously dealt with” (GOV/INST/SCI/TOX/2AUG13/TEL/IND) in India, although it will take time due to unavailability of sufficient reference data for nanomaterials. Though these guidelines are being developed for safe handling of nanomaterials in India, one University scientist, pointed out that “in practice what is followed is very difficult to understand” and “it is questionable.” (UNI/SCI/20AUG13/TEL/IND)

According to an organisation responsible for certification of food products for safety, most organisations, even in cases of non-novel products, often avoid doing even the simple tests and approach them only when the product fails, the client requires it or if the government mandates it. A scientist also pointed out that nanotoxicity tests are often avoided if nanoparticles are used in small quantities.

Organisations, though conscious of their responsibility on issues of health and safety, too did not have specific programmes to test toxicity of nanomaterials in their product. A large firm pointed out that, “safety for us is an ‘A class’ thing for the company” (ORG/MGT/INNO/31JUL13/TEL/IND) and all products are well-tested for safety and it is not just for products with nanomaterials. However, according to the founder of a start-up firm, safety issues pertaining to nanotechnologies will be addressed only when a problem arises, because that is how the culture is in India. According to the participant, people are more concerned about making money and if a problem does arise in future, it is then that they will pay attention to it.

“India is more accepting because, I’ll be honest with you, that’s how we deal with problems over here. When the problem arises, that’s when people seek a solution. We don’t gear ourselves up for problems beforehand... So people wake up to it after the problem has been created. So if nanotechnology for example creates a problem, only then will the rules come in. People are more worried about making profits, so they’ll make their money and if there is a problem that arises, we’ll see about it later... that’s
what the sense is over here. So it’s not like the Western countries where safety and you know a yellow jacket... I mean nobody cares about wearing lab coats over here in the laboratory...” (ORG/FD/31JUL12/TEL/IND)

Researchers at the National Dairy Research Institute (NDRI) have developed detection kits using gold nanoparticles, which will be applied to a packaging project for detection of adulteration in milk and contaminants in milk.

Some organisations are also conducting their own biosafety tests. Tests, such as the indemo toxico nanoparticle test, are also being carried out to test the toxicity of the nanoparticle in insects. Bio accumulation test is also being carried out to ascertain whether the nanoparticles used in their products are entering the food chain or the biological system.

The study also found various collaborative projects on nanotoxicity and risk assessment of nanotechnologies between India and developed economies like Australia, the USA, the UK, France, Germany and other EU countries. Research is carried out based on individual country’s expertise in certain areas and the availability of facilities in respective countries. The study found that tests, such as those on animals, are mainly carried out in India due to the difficulty of using animals for testing in certain European states like Germany.

6.3 Regulating nanotechnologies in India

Following an understanding of the trend in the R&D of nanotechnologies and the challenges faced in promoting F&FP (including agricultural) products of nanotechnologies in India, in the following section, I present the existing regulatory structure within India for F&FPN.

6.3.1 Priority in R&D and commercialisation over regulations

According to a participant at a food certification organisation “India is very serious about food safety regulation” (NFP/SR/FS/25SEPT13/IND) and the government is putting a lot of effort to ensure that every food business operator is able to supply safe food through the Food Safety Act enacted by the Central Government in 2011. However, when the question of whether nano-based products required clearances was put forward to a scientist at a government institute, the response was:
A participant from an organisation pointed out that they don’t face any problems using nanomaterials in their nano product “because there are not any rules established specifically to prevent us, any problems as such.” (ORG/FD/31JUL12/TEL/IND). Hence companies are able to research, develop and sell products without any issues of regulation.

While the Food Safety and Standard Authority of India (FSSAI) is responsible for setting safety standards for F&FP in India, currently they do not have any regulation for F&FP products incorporating nanotechnologies (see Appendix 16 for process for introducing a nano-packaging product). There is no statutory policy framework on the guidelines of use of nanomaterials, nor is there any provision “where it is encouraged or not encouraged” (GOV/SCI/11SEPT13/TEL/IND). Currently, all food products are tested under the same guidelines that are provided to test other food products for adulteration. For agricultural products too, there are no regulations on nanotechnology. Currently, any chemicals used in agriculture fall under the remit of the Ministry of Chemical and Fertilizers, and so as a scientist from industry points out “…there is [no] government agency… even no NGO… who can help us…” (ORG/SR/SCI/9AUG12/SKP/IND) on regulatory aspects of nanotechnologies. For pesticides, responsibility falls under the remit of the Ministry of Chemical Authority Liaison.

According to a manufacturer of a nano product for agriculture, products are not required to be registered unless it is a pesticide, a toxin or insecticide. If an approval for a pesticide is required, then they would have to get it from the Insecticides Board. If approval is required for a fertilizer, it would need to be registered under any of the four categories - inorganic fertilizers, organic fertilizers, bio fertilizers and chelated fertilizers - and approved under the Fertilizer Control Act. However, since the manufacturer’s bio-based nano-products do not fall under any of these categories, “we are not required to be registered under the FCO or Government and agriculture thing. So we are totally... on our own. That’s all” (ORG/SR/NANO/8AUG13/TEL/IND).

Thus, in the absence of guidelines for nanotechnologies, scientists and researchers follow their own specific institutional and company guidelines.
Moreover, with growing opportunities and “attention from the foreign partners” (ORG/SR/SCI/9 AUG12/SKP/IND) for international collaboration and business development, some smaller firms are self-regulating by carrying out various chemical and biological tests to ensure safety of their nano-products.

On the aspect of labelling, while one toxicologist pointed out that policy established by the DBT require manufacturers and producers to label products but is not mandatory, it was not apparent in other interviews with the other participants. Most participants resorted to digressing from questions on labelling.

Participants from government and firms are collective in their thinking that it may be too early to develop new regulations for nanotechnologies when India is still on a learning curve and only just getting to understand the technology. Moreover, a participant from a firm pointed out that while there has been much talk about nanotechnologies over many years, there are, as yet, not many products in the market. According to a policy-maker, regulators in India are waiting for the products to come into market before bringing in regulations. While the participant voiced concern and frustration about the challenges and delay in bringing out a policy, it was stressed that “most regulatory approvals would need a fine space evidence” (GOV/POL&SCI/19JUN12/TEL/IND) in order to implement regulations, particularly in cases of emerging technologies like nanotechnologies.

“I remember in 2006 when I start[ed] my work then, some of our own policy makers said, ‘why do you want to do a policy work now and trying to assess before. Let the products come.’ But then I am more of a personal opinion that we need to research much before the products actually come. So that’s how my stand was, and it’s not easy to convince even your own funding agencies the need for doing a policy” (GOV/POL&SCI/19JUN12/TEL/IND)

However, a scientist pointed out that the Indian government is more interested in promoting R&D in scientific institutions, and in developing a knowledgebase. Thus, a database which can be used by industry or can be used “to regulate or control the industry” (UNI/SCI/20AUG13/TEL/IND) has not been put together, nor has there been much effort on that aspect. This was corroborated by another scientist from government who indicated that
there is a lot of funding towards nanotechnology applications from the government, but nothing in terms of regulation or policy-making.

6.3.2 Questions of low regulatory regime in India

The aspects of low Indian quality products and the situation of low regulatory regimes as perceived by OECD countries was put forward to participants in India.

There were two sets of responses from scientists when they were asked about their perspectives on India being scrutinised for its potentially low regulatory regime by the West. Some scientists agreed that regulation in India is relatively lower than developed countries and is not their strong point, but argued that “it is increasingly increasing” (UNI/SCI/20AUG13/TEL/IND) and “evolving” (UNI/SCI/20AUG13/TEL/IND) whereby a number of testing laboratories are being newly established and various advance tests are being carried out in these labs. According to some participants, India is slowly making efforts to improve its standards so that it is able to sell products in developed countries that demand higher standards and do not allow products into their markets if it is found to not have undergone stringent tests. Moreover, as one participant from a firm pointed out, if they were to launch a truly innovative product, a “potential commercial time bomb” (ORG/FD/31JUL12/TEL/IND), in order to make that really successful they would have to ensure that the product is safe because “as a company, to protect integrity is more important than money” (ORG/FD/31JUL12/TEL/IND). Hence, they are willing to invest as much money as possible to ensure safety of nanotechnologies and are also willing to carry out further tests to resolve all issues before launching any product. A university scientist also pointed out that any nano projects that are taken up have to be approved by the ethics committee based at various institutions (UNI/SCI/FD/29JUL13/TEL/IND).

On the other hand, some scientists questioned regulations in developed economies like the U.S. and Canada where controversial GM technology is being used in the cultivation of canola and soya bean and “they don’t care about it” (UNI/SCI/15OCT12/TEL/IND). Participants also pointed out that there should be more concern about countries like China and Thailand that are developing “hundreds of nano-based products” (UNI/SCI/15OCT12/TEL/IND) and where “tons and tons of these nanomaterials are being made” (GOV/SCI/EHS/6SEPT3/TEL/IND). A scientist from a government institution also emphasised that none of the other countries
around the world have as yet come up with regulation, and so India too is at a “primitive stage” (GOV/INST/SCI/TOX/2AUG13/TEL/IND) and there was thus no question of regulation.

Participants argued that there is an unfair judgement on products with a ‘Made in India’ tag, even though products from countries like China are far more questionable. According to participants, products incorporating nanomaterials are often sent to OECD countries for testing, and “are all of international standard” (GOV/INST/SCI/TOX/2AUG13/TEL/IND) and thus should not be discriminated just because they are manufactured in India.

“Yes, this question sometimes makes us, we people, laugh because we are sitting in India and we are doing like world class kind of the research... So what I mean to say this is not true that every time all the Indian products are being tested in India only. So this is a kind of the thing that we need to make understand the other foreigners that we are having the quality product and like we have our rival country... we don’t want to do something like that, even though we would like to do... Our product should speak, shouldn’t our geography should speak.” (ORG/SR/SCI/9 AUG12/SKP/IND)

An Indian promoter of nanotechnologies also questioned safety standard tests for nanotechnologies in developed countries, pointing out that the issues of safety pertaining to nanotechnologies are the same everywhere. According to the participant, even though not many people would want to use Indian products, “there is[n’t] any stringent thing which they have done there which can’t be done here.” (ORG/PRO/23JUL&2AUG13/TEL/IND). The participant narrated the case of a nano product manufactured in India and marketed to U.S. clients via channel partners based in the U.S. However, when the Indian manufacturer approached a U.S. company directly to sell the product, the company declined the offer on the grounds that they were already using a similar product from the U.S. On investigation, it was found that the product used by the American company was the same product that was purchased from the U.S.-based suppliers of the Indian manufacturer.

There were similar opinions from other participants on the role of the international community. Various participants from firms complained about the international community’s unwillingness to share the data on safety issues of nanotechnologies. A scientist complained about the nonchalant attitude of highly-regulated regions like the U.S.A. in matters pertaining to
nanosafety and the lack of interest from the EU where there appeared to be no effort in sharing data on nanotoxicity issues despite numerous requests.

“But what about regulations in the U.S.? I’m sorry that regulation in India might be at a lower end but look at US, what are they doing? They are absolutely silent on this matter and at many forums I have said this loud and clear, people don’t like it. But why has U.S. shying away. They should take the lead on this. Look at their EPA site, look at their FDA site, they are absolutely silent on this... Infact, I have tried to get in touch with FP7, and those Nanotox and those Eurotox... they were not forthcoming. I don’t know why... Why don’t they open up their data for everybody, better put it in the public domain? Anybody can question me. I asked so many emails... but none of them replied. I don’t know why.” (GOV/SCI/EHS/6SEPT3/TEL/IND)

As one founder of a small firm put it, by sharing data it would not only be beneficial to developments in regulation of nanotechnologies, but it would also open markets between countries as it will be “very easy for foreign countries to just forward that information and create rules and regulations in their respective countries through what India has provided”. Moreover, it will provide the Indian government the information required for tax purposes.

Another manufacturer who was invited to a meeting of the Advisory Committee of Hazardous Substances in London, narrated how they received much backlash from other participants at the workshop with regards to the use of (a very small amount of) cobalt in their product. The participant argued that some of the materials are required for both plants and the human body and that the scientists in the West “have this narrow mind that something is harmful, that it should not be there, it’s a dangerous, this thing or that...” (ORG/SR/NANO/8AUG13/TEL/IND). According to the participant, Western scientists are much more interested in publishing papers than looking at what value science and technology can bring to benefit society and argued that such stances on what is right or wrong are unavoidably dictated by powerful Western societies.

“So they take things in isolation and blow it out of proportion and write lot of papers on that and claim to be great scientist, but ultimately they are not delivering anything of value to the society at large. They’ll be harming the society more rather than helping the development of science and technology. So what to do some societies they are more
powerful and they are... able to dictate what’s right and what’s [wrong]…”

(ORG/SR/NANO/8AUG13/TEL/IND)

6.3.3 Discussions on policy issues

While there is no established nano policy in India, the study found that the need for policy is being discussed by senior scientists at various committees, and a policy is being drafted. The GoI has initiated the process of developing a regulatory framework for application of nanotechnologies though “that framework is under evaluation, it’s not yet completed” (GOV/SCI/18SEPT13/TEL/IND).

The DST and scientists from various organisations and research institutions, including senior scientists from government institutions, NGOs and farmers are involved in debates in these regulatory framework committee meetings. Some scientists and government officials pointed out that during the GMO revolution many stakeholders were not invited to participate on policy debates, which resulted in negative repercussions. To ensure that a similar public backlash does not occur with nanotechnologies, stakeholders from different regions are now being involved in policy debates on nanotechnologies. According to government officials, industry, scientists, bureaucrats and technocrats are invited on standards and regulatory committees for nanotechnologies in India. They involve participants from various government agencies, such as different ministries and government bodies, including the DBT, ICMR and NPL, in most policy debates and discussions. Most are “specialist[s], they have been involved with this activity deeply” (GOV/SR/NANO/26JUL13/TEL/IND). Discussions in these regulatory panel meetings focus on safety of workers in the labs, risk hazards of nanoparticles, health related issues and risks of nano products. These working group meetings happen at least twice a year.

R&D representatives from academia/institutes are also invited on these nanotech policy panels. NGO/CSO representatives that have been “vocal and concerned about these things” (UNI/SCI/FD/29JUL13/TEL/IND) are also present in discussions. However, while scientists in research institutes did acknowledge that NGOs are important to the success of any new and emerging technologies and should participate on regulatory panels, a senior government official stressed that NGOs could not be part of standards and regulatory committees because they did not have the knowledge or understanding of new technologies.
Few firms, especially large firms are invited to participate in policy debates by the government. One particularly large firm is working with the GoI to see whether there are some regulatory aspects that need to be established for nanotechnology in agriculture. Feedback on new policies are also sought through active links with industry associations for new technologies, though the study indicated that in the case of nanotechnologies these have not yet been initiated.

6.3.4 Call for regulation

At least two participants from smaller firms called on the GoI for regulations to be put in place, which would not only help them get funding but also allow free trade across borders. According to them, they are “troubled very easily and very often by the government itself” at Customs when importing nanomaterials and so they are calling for “some sort of regulation allowing free passage of nanoparticles all across the world” (ORG/FD/31JUL12/TEL/IND). Moreover, the Customs and Excise Department are unable to classify the products when it comes to issues on manufacturing duty and rates of tax. They elaborated on the need for regulation as it would help “authenticate” (ORG/SR/SCI/9 AUG12/SKP/IND) their work on nanotechnologies and they would also be able to approach funding bodies for funds that would enable them to carry out necessary toxicity tests. They called on the GoI to be more pro-active and “wake up to the fact that nanotechnologies [are] becoming really big” (ORG/FD/31JUL12/TEL/IND). This was reiterated by a toxicologist who stressed that there is “need for a national regulatory authority for nanotechnology.” (UNI/SCI/EHS/17SEPT13/TEL/IND).

However, a scientist from a university pointed out that regulating science is a “complex game” (UNI/SCI/16AUG/TEL/IND) and unless there is hue and cry from the general public or a tragedy, it is most unlikely that the government will wake up to regulating nanotechnologies or that the organisations will self-regulate.

On the other hand, a manufacturer questioned the need for regulation unless the product is harmful. The participant argued that while “regulation is the easiest thing a country can do” (ORG/MGT/INNO/31JUL13/TEL/IND) yet there has been little progress in regulating pollution, sewage and plastic that are thrown into open water bodies. According to participants, by calling for regulation in nanotechnologies it will “stifle innovations straight and clear” (ORG/SR/NANO/8AUG13/TEL/IND) and companies will “be more worried about the laws than doing any innovation at all” (ORG/SR/NANO/8AUG13/TEL/IND). One participant went
on to argue that in India, those likely to set regulations for nanotechnologies are unlikely to understand it themselves. On the other hand, in other parts of the world “people want to regulate-regulate-regulate” (ORG/SR/NANO/8AUG13/TEL/IND) even though there are various unsolved problems in the world. The participant argued that instead of “trying to stifle innovation that can solve these problems, it’s better to recognise the innovations and take it in the direction that can give maximum benefit to the society at large.” The government should thus have a policy that can be used to evaluate new nano products, and if there are certain processes or particles that are harmful to the environment, then “a one line or two line guidelines may be more than sufficient”.

Some participants believe that it is likely that more advanced countries will develop regulations and India “will be forced to follow” (ORG/PRO/23JUL&2AUG13/TEL/IND) as has always been the case in the past. A participant from a food certification company agreed that regulations will not come from India first but will be initiated from other nations, such as the EU, because India has not reached “that level where we are considering nanotechnologies to help us to sustain or prepare the food” (NFP/SR/FS/25SEPT13/IND).

6.4 Responsibility/RI

The previous sections provided an understanding of the regulatory structure for the governance of F&FPN in India. In this section, I will investigate the notions of ‘responsibility’ as perceived through the lens of governance actors in the nanotech food chain. In this endeavour, the section will first discuss what responsibility means to various actor groups and who these actors consider is responsible for the safe and ‘responsible’ research and development of nanotechnologies.

6.4.1 Perceptions of ‘responsibility’

There were varied perceptions of ‘responsibility’/RI among different actors in India. According to a majority of actors, including some scientists, government officials, and organisations, ‘responsibility’ in innovation is perceived as innovation which directly benefits people and which does not cause adverse environmental impacts.
According to some scientists, ‘responsibility’/RI is about achieving “social or environmental benefit, both now and in the future” (SCI/GOVT/INST/1AUG13/EMAIL/IND), which “improves the livelihood of people” (UNI/SCI/15OCT12/TEL/IND), and “makes a difference to the lives of people” with low-income (UNI/SCI/FD/29JUL13/TEL/IND). Another university scientist relates responsibility as “doing good science” with the aim of creating useful technology or products. To other scientists, it was about creating “environmentally-friendly” innovative solutions that “enhance[s] the productivity of the crops or the animals” (GOV/SCI/14SEPT13/TEL/IND), and ensures that it does not create environmental problems but is done in a manner which is “sensitive to the needs of future generations” (ORG/MGT/INNO/31JUL13/TEL/IND), where societal actors and innovators are mutually responsive to each other.

Among participants from firms, responsibility pertains to socio-economic benefits for mankind. According to a participant from a small organisation, their products help firms and farmers to benefit from higher yields and better quality end-products. Thus, their idea of responsibility is to be able to “serve the society” (ORG/SR/SCI/9AUG12/SKP/IND), and especially “serve the farmers” (ORG/SR/SCI/9 AUG12/SKP/IND) by increasing their income through higher crop yields, and helping younger farmers to be able to support their families and not having to immigrate to urban regions to look for jobs. Responsibility in innovation is bringing “better benefit to... mankind at large” and solving “all that problem by a simple method.” (ORG/SR/NANO/8AUG13/TEL/IND) and increasing their “quality of life” (ORG/MGT/INNO/31JUL13/TEL/IND). A participant in a safety certification organisation believes that RI is about using technologies to focus on issues like hunger and poverty where food with maximum nutrition and with minimum cost can be provided to the poor.

‘Responsibility’/RI is understood by one scientist to be able to develop the technology through the support of the government that “understands the responsibility to fund these projects” (GOV/SCI/21AUG13/TEL/IND).

For government officials, responsibility is about creating products that are commercially viable. It is about having an understanding of what works and what does not and is “acceptable economically” (GOV/SR/NANO/26JUL13/TEL/IND). According to the participant, it is also about having sufficient data to ensure that it does not lead to harmful products, though it would
be the responsibility of the society to keep a check on that, if it does lead to some bad use. A policy-maker pointed out that responsibility is “based on the needs of the time” and “on needs of various segments of the society” and “whether it makes commercial sense in a manner that an enterprise could be created around it” (GOV/SR/19SEPT13/TEL/IND). Another policy-maker stressed on transparency as ‘responsibility’ through information, communication and engagement of stakeholders, especially in sectors like agriculture where actors, such as farmers involved in such innovations are “unacquainted” (GOV/POL&SCI/19JUN12/TEL/IND) and unaware of the dangers and risks involved in using such disruptive, new and emerging technologies.

Some perceptions of participants focused on safety of products where “biosafety is the topmost priority” (UNI/SCI/EHS/17SEPT13/TEL/IND). According to a scientist from) an organisation (ORG/SR/SCI/9AUG12/SKP/IND, in order for nanotechnologies to achieve success, there should be public awareness and long-term in vitro and in vivo toxicology tests to ensure environment and health safety. These tests should be conducted by an independent nanotoxicity body. The participant stressed that a Central Instrumentation Facility (CIF) should also be set up by the government where organisations without funds are able to carry out various tests for their products to ensure safety. A similar view is taken by another participant in an organisation (ORG/FD/31JUL12/TEL/IND), that ‘responsibility’/RI is about ensuring the safety of the product, environment, animals and humans, through rigorous assessment before it is launched. According to a manufacturer of nano-products responsibility is about self-regulation where “companies themselves will have to regulate” (ORG/SR/NANO/8AUG13/TEL/IND) to ensure that the products are safe for the environment, animals and human beings before launching it, and understand that they are liable for any adverse effects of the product.

There is also the notion among scientists and participants in organisations that ‘responsibility’/RI is about replacing some of the existing hazardous chemicals and pesticides in agriculture with “environment friendly” (ORG/SR/SCI/9AUG12/SKP/IND) nanotechnologies. It is about effectively using agricultural waste to create packaging materials which can substitute some of the chemical-based plastic products.

However, a participant from an NGO, had a different view about ‘responsibility’ in nanotechnologies. The participant related ‘responsibility’/RI to the period/point in time when
it is developed and considered innovative. Using the analogy of lead in gas, the participant pointed out that when lead was used in gas, it was seen as a great discovery and achievement at the time, but today advance research has found that lead is harmful to the environment. Hence, according to the participant what appears to be “honky dory” (DIR/NGO/16SEPT13/TEL/IND) today may not be considered as responsible down the years due to some unforeseen circumstance. Similarly, nanotechnology may appear to be beneficial now but could down the line prove to be harmful.

6.4.1.1 Varied notions of safety

There were varied notions of safety among participants. Some scientists argued that nanotechnology is there from ancient times. A scientist/founder of a company also pointed out, “a lot of our traditional medicines involves use of nanomaterials, you know... it’s not all that new”. (UNI/SCI/FD/29JUL13/TEL/IND). However, a university scientist argued that not all nanomaterials are safe though they have been used since ancient time. Taking the example of Ayurveda, another participant argued that some of the drugs prescribed in Ayurveda are in metal nano forms, and according to Ayurvedic belief these heavy metals are not harmful because of their very small size and it would pass through the body without damaging organs. According to the scientist, while there are strict protocols58 to be followed when developing the drugs, “unless there is a[n] absolutely strict quality control, they could be actually very dangerous.” (UNI/SCI/16AUG/TEL/IND).

There is also a view among participants that if products, incorporating nanomaterials, are tested in OECD countries or approved by them, then the products are safe and require no further testing or certifications as they have been tested by countries that follow stringent safety laws.

“...our products are so well established that we don’t need any safety certificates. I mean they’re all based on German technology and Germany has very stringent rules of safety and use.” (ORG/FD/31JUL12/TEL/IND)

Some participants from organisations insist that nano products using plant-based materials are safe because they are using “pure minerals” (ORG/FD/AGRI/9AUG12/TEL/IND) directly

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58 Such as what materials to use, what temperature to maintain, etc.
extracted from the plant, and even if they enter the environment “nothing is going to happen because the size is small…” (ORG/PRO/23JUL&2AUG13/TEL/IND). Moreover, these nano nutrients are required by the plants and “it’s totally negligible” (ORG/SR/NANO/8AUG13/TEL/IND) when added to a product and cannot be seen through organic or inorganic testing. According to another participant, if a product that was tested passed eight out of ten safety tests then it was sufficient and “maybe you can go ahead and prove that to others” (UNI/SCI/20AUG13/TEL/IND).

However, a biosafety university scientist points out that since nanotoxicity protocols are not well established, companies that produce nano products undertake conventional safety tests and say that their products are safe and “flood their products in the market” (UNI/SCI/EHS/17SEPT13/TEL/IND). Moreover, companies are unwilling to provide any information on the materials used in their products on the pretext that the product is patentable or it is confidential business information. Under such conditions that “their product is very competitive” (UNI/SCI/EHS/17SEPT13/TEL/IND), the scientist points out that, these companies do not undertake thorough biosafety tests on their products and thus escape the regulatory system. According to the participant, while some reputable companies that have nano products in the market are “responsible organisations” and “they go for ethical ways of innovation” (UNI/SCI/EHS/17SEPT13/TEL/IND), it is unclear whether they are aware of the safety protocols and tests that need to be undertaken. Furthermore, there is no clarity on how the nano products are used after they are sold; it is entirely left to the buyers how they use it or whether they are following the instructions that come with the products.

Some participants in organisations elaborated that their products are safe because these have been certified as organic or are due to be certified as organic. For example, a participant from an organisation (ORG/SR/NANO/8AUG13/TEL/IND) points out that a toxicology test was undertaken on their nano-silica based product developed for fisheries and agriculture by the mulberry research institute, Karnataka State Sericulture Research and Development Institute in Thalaghattapura, Bangalore, and the product is due to be given a safety certification by them.
Similarly, ORG3 is currently trying to get approval from the Tea Research Association\(^{59}\) to get one of their products for tea certified as organic.

However, as Indian certificates are often not effective for international exports, ORG3, whose products have been used in the U.S.A.is now trying to get a certification from the Organic Materials Review Institute (OMRI) in the U.S., which provides an independent review on products for organic use so that they are able to export their products freely to other developed economies.

FDA certifications, such as GRAS (Generally Recognised As Safe) status in the U.S. is also perceived as a recognition of safety by participants.

**6.4.2 Who is responsible?**

According to various participants, nanotechnology is highly collaborative and integrated, hence everybody in the nanotech food value chain is responsible for the safe development of nanotechnologies. A majority of the participants were in consensus that everyone has “*shared responsibility*” and that it is a “*collective effort*” (GOV/INST/SCI/TOX/2AUG13/TEL/IND). It is not the responsibility of a single person but is “*multi dimension*” (GOV/POL&SCI/19JUN12/TEL/IND) and “*everybody who promotes an experiment*” (DIR/NGO/16SEPT13/TEL/IND) is accountable. According to participants, it requires more than one institute to work “*in synergy*” (GOV/INST/SCI/TOX/2AUG13/TEL/IND) because not only does the product have to be tested for their efficacy but also for its safety.

A participant from a food certification organisation points out that while government is the ultimate entity that is responsible “*you can't just blame the government but every stakeholder*” (NFP/SR/FS/25SEPT13/TEL/IND); everyone from the producers to the middle men to the farmers are responsible. Even the consumers are considered to have some ‘responsibility’ because they need to ask questions about what goes in their food and how safe it is. According to a scientist in a public institute, each and every person using nanomaterials is accountable, be it a big firm or a small company. Thus, ‘responsibility’ extends from “*farm to fork*”

\(^{59}\) A body that does research on all aspects of tea cultivation and processing at the Tocklai Experimental station in Jorhat in Northeast India
(GOV/POL&SCI/19JUN12/TEL/IND), from a grower to researchers and the developmental agencies implementing the new technology, to manufacturers/ producers, retailers and consumers.

However, most scientists acknowledged that ‘responsibility’ starts from “the researcher’s point of view” (GOV/POL&SCI/19JUN12/TEL/IND) and thus ‘responsibility’ pertaining to safety of nanomaterials is mainly with the scientific community because as scientists they are developing materials that would be used in products and sold in the market. Moreover, “the scientist is the most well-informed person” and is “not supposed to have any vested interest”, hence the responsibility should be theirs.

Some other scientists, however, disagreed and pointed out that there is a scientific gap in relation to nanotechnologies, and hence for scientists to take the entire responsibility may not be possible. According to them, the government should also have some responsibility. Government agencies such as the Export Authority of India should oversee the responsibility and accountability of safety of nanomaterials as they regulate the entry and exit of goods in India. A participant from an industry association concurred that it was the responsibility of government that supported such products, because when “products are marketed, its impacts are valued by stakeholders if supported by government and then it automatically catches fire” (ASSO/SR/INNO/26JUL13/TEL/IND). A government official, while agreeing that the responsibility is with government “for ensuring the safety” (GOV/SR/19SEPT13/TEL/IND), also maintained that some responsibility lies with CSOs/NGOs as they oversee various activities and “keep sort of sensitising the government” (GOV/SR/19SEPT13/TEL/IND).

According to a scientist working on biosafety at a university, the first ‘responsibility’ should fall on scientists because they are the ones that are confident enough about the safety of products before sending it outside of their lab; and the second responsibility should be taken by government agencies because they fund projects and set laws and regulations. However, the participant goes on to point out that the stakeholders or users of nanomaterials, such as the farmers, are equally responsible and should be given the third responsibility because if they do not follow the instructions given to them on how to use the product, then it could lead to adverse effects. This was also reiterated by a manufacturer that was willing to take the responsibility to ensure that the product is safe, but pointed out that the users of the products, such as farmers,
should also take ‘responsibility’ to ensure that they use the products correctly and feedback honestly.

Some scientists pointed out that developers of the technology, that is, R&D organisations and the companies, should be responsible but did not believe that they will take ‘responsibility’, so it should be overseen by government regulatory bodies, NGOs and members of the civil society. According to a senior toxicologist, proposals that are submitted and funded by the government, have well-defined objectives. If investigators fail to fulfil the objective, then the ‘responsibility’ should lie with them.

Some scientists, however, are sceptical about ‘responsibility’ from industry because they believe that industry are more keen to get products out in the market and often use the term ‘nano’ as a buzzword without understanding its meaning. A policy-maker, while corroborating this aspect, agrees that there are certain industrial giants that use the word ‘nano’ “for promoting their commercial presence in a positive way” (GOV/POL&SCI/19JUN12/TEL/IND) without understanding the repercussions.

However, a manufacturer pointed out that the manufacturers take all the risks in developing new and innovative products and placing them in the market. If anything goes wrong, people will always point a finger at the manufacturers and so they always take “a cautious step” (ORG/FD/AGRI/9AUG12/TEL/IND) because the government is not willing to take any risks in directly approving products. Furthermore, it was pointed out that organisations today are not willing to take risks that would harm customers or even their employees as they do not want to be liable to pay compensation and jeopardise their reputation. Moreover, the law always catches up with such organisations, hence “if the risk factor is there they will probably not touch it if it’s harmful” (ORG/SR/NANO/8AUG13/TEL/IND).

A participant from an NGO, further added that all institutions that work on innovation are “fairly sincere” and “mean good” (DIR/NGO/16SEPT13/TEL/IND) and cannot be accused of being irresponsible but do their research with the best intentions and seriousness. However, a participant from an association pointed out that the industry is “looking for receptive solution” as they see a “balloon market” in the food industry (ASSO/SR/INNO/26JUL13/TEL/IND).
Participants from organisations (ORG1, ORG2 and ORG4) that are manufacturing various nano products, held government regulatory bodies and food safety authorities as the first entity responsible for the safe and ‘responsible’ development of nanotechnologies as they are the “licensee” that give authority to place the product in the market. The second ‘responsibility’, according to them, should go to the manufacturer developing the product as they are responsible to ensure the product is safe. According to them, it is “organisations’ responsibility or irresponsibility, both are there” (ORG/SR/NANO/8AUG13/TEL/IND) and problems can be linked back to organisations that manufacture harmful products. This would ensure that any companies that are “messing around” (ORG/FD/31JUL12/TEL/IND) with nanotechnologies will be liable to report to an authority. Moreover, lawsuits are powerful that can destroy companies, which companies would want to avoid. It is thus the responsibility of the government to keep organisations in check by reminding them of their responsibilities.

6.5 Nanotechnologies in food and food packaging

The aim of this section is to provide information on the various nanofood and packing projects currently underway at various public institutions and firms in India. Interestingly, this study found many cases of transnational research networks between India and developed countries, which has been investigated in this section.

6.5.1 R&D of F&FPN at public and private Institutes

According to some participants from firms, R&D of nanotechnologies in F&FP in India is still at a nascent stage and “it hasn’t picked up in a big way in India at least” (ORG/MGT/INNO/31JUL13/TEL/IND) because “the market is not there so why should somebody put money into production?” (ORG/PRO/23JUL12AUG13/TEL/IND). Participants from the scientific community also confirmed that industry level implementation of nanotechnology has not as yet picked up and majority of R&D in nanotechnologies in F&FP are carried out in government institutes. Project proposals from these institutes are often assessed and funded by government, based on development needs of society, and are also expected to be commercialised. New technologies are often patented with the intention of finding collaborations with industry.
However, various projects are underway at different government-led universities and institutions in India on nanotechnologies in F&FP. These focus on encapsulation of (beneficial) food material for flavours, anti-oxidants or vitamins, food packaging and sensors or smart filters, besides others.

The study found many R&D and applications of nanotechnologies in F&FP, water purification poultry farming and agriculture. Private companies and government agencies, such as ICAR and the NAARM, are conducting various R&D programmes that focus on improving nutrient utilization and efficiency in crops and nutrient uptake in plants through delivery systems. While nanotechnology development in agriculture is still at an infancy stage in India, its use is explored through some of the existing developed technologies in other sectors, where various technologies are being extended in sectors like agriculture, animal husbandry, poultry or the fishery sector, rather than starting a new research. For example, the drug delivery system developed for the health industry is being explored for nutrition uptake by crops in agriculture.

R&D in nanotechnologies is also being conducted in the fishery industry by government-led institutes such as The Central Institute of Fisheries Technology (CIFT). Small private firms are also conducting various preliminary research and have developed products for the fishery industry.

In water technology, there is an assortment of nanosilver-based water filters already in the market. Developed to cater to the demand for purified, bacteria-free water in both the rural and urban regions, the silver coated nano membrane for the water filter was first developed by the government-led IIT in Chennai. The technology was later shared with a well-known Indian company that developed a water filter, which is currently on sale in towns and cities. While the commercialisation of the product did not require nano-specific government approvals, it had to meet Indian standards of purifications and product attributes; for example, the plastic used in the product had to be of food grade quality.

6.5.2 International collaborations in nano F&FP

Researchers in India are involved in various collaborative projects with developed countries on nanotechnologies in F&FP, including with the U.S.A., Japan and some European countries, such as UK and France.
Many of these collaborations and interests were from organisations and institutes in Canada. For example, researchers/scientists at IIT, New Delhi, are working on a joint collaborative project on nano-packaging with the University of Guelph in Canada, to develop film-moulded products with barrier properties. At TNAU, scientists are working with the University of Guelph to create a nano-film for packaging that can be used to extend the shelf life of fruits, specifically mangoes in India (See Case Study: The Mango Story in Chapter 5, section 5.5.2.1). The research also involves a biosafety element, which is carried out in India. Both the projects are supported by funding agencies in Canada and are expected to receive extended funding for the projects.

An Indian scientist from IIT Mumbai based at University of Alberta along with researchers at IIT Bombay and the Centre for Environmental Science and Engineering are in discussions to start an Indo-Canadian collaborative project on water.

Table 16 in Appendix 17 provides a list of some of the public and private sector nano-based R&D projects and products in India.

6.6 Conclusions

6.6.1 Summary of findings and analysis: Case of India

The transformational potential of nanotechnologies has received much interest among the scientific community and governments around the world. Due to globalisation there is a potential for a growth in markets for nanotechnologies not only in developed countries, but in developing countries and emerging markets. Several developing nations have harnessed nanotechnologies initiatives where it is expected to provide not only economic and industrial benefits but also address some of the Millennium Development Goals set by the UN.

As an emerging market, the case of India sought to understand the current governance landscape of nanotechnologies in a regime of (potential) low regulation and explore notions of ‘responsibility’/RI as it is seen through the perceptions of different actors in the nanotech food chain.
Findings through interviews with actors from government, industry, universities, civic societies and the scientist community identified five unique scenarios in governing the R&D and commercialisation of nanotechnologies in F&FP in India:

i.  *Government-driven initiatives and investments in research and innovation to address societal challenges:* The initiatives for R&D of nanotechnologies in India is powered by the GoI as a means of solving some of the societal grand challenges set by the UN. Extensive numbers of projects with a focus on societal needs are currently being funded by the government and propagated at various public institutions in the areas of F&FP (including agriculture), thus promoting an open innovation culture.

ii.  *Use of NGOs/extension agents to educate farmers and promote products incorporating nanomaterials:* With lessons learned from GMO and biotechnology, many institutes and organisations use NGOs in India to gain support from farmers and the local public in rural areas for field tests of nano-based products. This unique model focuses on not only increasing the awareness of nanotechnologies to rural regions but also in helping appease any potential public backlash from the use of such new technologies.

iii.  *Consumer choice where attitudes towards nanotechnologies is framed by transparent and open dialogues by firms, transparent labelling and celebrity advertising.* Firms/entrepreneurs and researchers were found to be very open and overt about their research on nanotechnologies in India as they see innovations using such new and emerging technologies as a way of helping the poor and improving their livelihoods. Consumer choice is thus influenced by presence of nano-labelled products in the market, coupled with celebrity branding of nano-products in advertisements.

iv.  *Putting trust on scientific knowledge and expertise, and reputable organisations for the ‘responsible’ development of nanotechnologies:* Various products of nanotechnologies are promoted/installed in rural regions, or sold in urban markets based on the trust in knowledgeable scientists and reputable organisations that are revered for their high quality products. The promotion of these products involve various promotional and communication strategies involving radio, television and print media.
v. Focus on ‘responsible’ development of nanotechnologies through global collaborations with developed countries: Various government-led institutions in India are working on a range of collaborative projects with OECD countries in the areas of F&FP and nanotoxicity, where responsibility in innovation is fostered through the transfer of expertise and integration of responsibilities through a heterogeneous group of actors across geographies, and biosafety criteria set by nations with high regulation/standards. Notions of ‘responsibility’ is also arguably justified through testing of products in international territories, approval and use of Indian (nano-based) products in developed countries, and compliance through local and international certifications.

6.6.2 Connecting to Chapter 7

In this chapter, I summarised the main findings from the analysed data gathered from my second cases, India, an OECD-interest country. Using the findings from this chapter, I will investigate my two research sub-questions to gain an understanding of how the regulatory governance mechanisms and notions of ‘responsibility’ affect geographies and markets of nanotechnologies in this region.

In the following chapter, I will address my two research questions using the findings of my two case studies from Chapter 5 and Chapter 6. While answering the research questions in Chapter 7, I will discuss the commonalities and differences in the governance of nanotechnologies in the two regions/cases, through a comparative case study analysis.
CHAPTER 7

DISCUSSING THE GOVERNANCE OF NANOTECHNOLOGIES IN CANADA AND INDIA THROUGH COMMONALITIES AND DISPARITIES IN REGULATION AND NOTIONS OF RESPONSIBILITY

7.1 Introduction

7.1.1 Connecting to previous chapters

The main objective of this research was to investigate the notions of ‘responsibility’ as seen through the lens of governance actors in the F&FP sectors in two diverse regulatory settings. I sought to investigate this notion of ‘responsibility’/RI by examining three research questions, a main question and two sub-questions provided in Chapter 3, section 3.3. Based on these research questions, the previous Chapters 5 and 6 provided detailed findings and analysis of qualitative interviews with 70 participants (44 in Canada, and 26 in India). These interviews specifically focused on analysing the existing governance landscape through national regulation/governance regimes, and the normative framings of technology and notions of ‘responsibility’/RI as interpreted by actors in each region. So far, these findings revealed five unique scenarios in each of the two cases of my study, Canada and India, as summarised in Table 7 below. These different domains of ‘responsibility’ exposed various commonalities and disparities in the governance of nanotechnologies in F&FP in Canada and India, which is outlined in Table 8.
<table>
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<tr>
<th>NO.</th>
<th>CANADA</th>
<th>INDIA</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>Encouraging and promoting domestic R&amp;D and commercialisation, including public-private partnerships</td>
<td>Government-driven initiatives with majority of research being conducted in public research institutions to address societal challenges</td>
</tr>
<tr>
<td>2.</td>
<td>Establishing programmes/initiatives by making available funds through set criteria that encourage focus on the ‘responsible’ development of nanotechnologies</td>
<td>Inclusion of NGOs/extension agents to appease potential backlash, educate farmers and promote products incorporating nanomaterials in rural areas</td>
</tr>
<tr>
<td>3.</td>
<td>Regulating through existing stringent policies and new legislations for novel F&amp;FP products, and new standards and policies developed through bilateral initiatives and participation in international regulatory committees</td>
<td>Consumer choice where attitudes towards nanotechnologies are framed by transparent and open dialogues by firms, labelling, celebrity advertising and open innovation culture.</td>
</tr>
<tr>
<td>4.</td>
<td>Involvement of citizens’ groups/ heterogeneous group of actors in Canada’s policy debates</td>
<td>Putting trust on scientific knowledge and expertise, and reputable organisations for the ‘responsible’ development of nanotechnologies</td>
</tr>
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<td>5.</td>
<td>Developing transnational research networks in emerging countries, from where there is the possibility that Canada would, in future, allow entry of nano-products into its markets</td>
<td>Focus on ‘responsible’ development of nanotechnologies through EHS research in transnational networks and collaborations, and distributed responsibilities</td>
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*Table 7: Scenarios of governance of nanotechnologies in Canada and India*
<table>
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<tr>
<th>CANADA</th>
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<tr>
<td><strong>R&amp;D AND FUNDING OF NANOTECHNOLOGIES</strong></td>
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<tr>
<td><strong>R&amp;D in Nanotechnologies</strong></td>
<td>For health and economic benefits; commercialisation</td>
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<tr>
<td><strong>Public-private partnerships</strong></td>
<td>With industry - expected to increase</td>
</tr>
<tr>
<td><strong>Funding availability</strong></td>
<td>Government-supported funding for research with health, economic and social benefits</td>
</tr>
<tr>
<td><strong>Resources for industry</strong></td>
<td>Govt. funding provided to organisations; match-funding with industry</td>
</tr>
<tr>
<td><strong>REGULATIONS</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Guidelines for workplace</strong></td>
<td>Recently implemented (CSA Z12885)</td>
</tr>
<tr>
<td><strong>Standards &amp; Regulation</strong></td>
<td>Use of cellulose nanocrystals (CNC) approved; established a definition for nanotechnologies in 2011</td>
</tr>
<tr>
<td><strong>International cooperation on regulatory issues (e.g. ISO, OECD WPN)</strong></td>
<td>Very active; Active participants in the international arena on nanotech regulatory debates</td>
</tr>
<tr>
<td><strong>Regulatory collaborations</strong></td>
<td>With US (e.g. RCC)</td>
</tr>
<tr>
<td>Industry participation in policy debates</td>
<td>Plays a key role in policy debates – both large and small firms</td>
</tr>
<tr>
<td>Policy debates</td>
<td>Many policy debates with active participation of different actors, including NGOs</td>
</tr>
<tr>
<td>Role of actors in policy-making debates</td>
<td>Most actors have more than one role</td>
</tr>
</tbody>
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### NOTIONS AND PRACTICES OF ‘RESPONSIBILITY’/RI

| Notion of responsibility | Focus on health and safety of human health and environment; risk aversion | Focus on alleviation of poverty and meeting grand challenges; benefit for society |
| Perception of who is responsible | Shared responsibility | Shared responsibility |
| NGOs | Active international players asking for a moratorium on R&D in nanotechnologies | Working with scientists and farmers to promote new and emerging technologies who see nanotechnologies as a benefit |
| Focus on issues of EHS/ELSI | Growing number of funding for research focusing on these aspects | Lacks funding and research but collaborating on many nanotoxicity research projects with OECD countries |
| Transparency of corporations | Cautious about disclosing or showing interest; afraid of backlash | Very overt; see it as a moral responsibility in helping society |

### MARKETS FOR NANOTECHNOLOGIES

| Products in market | Packaging | F&FP, agriculture; fruits; fish; water – already exporting |
| Future markets for F&FP | Nano-packaging; cautious about food | Mainly nano-packaging and agriculture but some in food |

*Table 8: Commonalities and disparities: Cases of Canada and India*
7.1.2 Purpose of this chapter

Focusing on the varieties of notions of responsibilities, as discussed in the previous section, in this chapter, I will discuss the main findings, using the summaries from Chapters 5 and 6, through a comparative case study analysis between Canada and India.

The five scenarios in Canada and India are discussed and compared while reflecting against existing theory and literature. The purpose of this chapter, therefore, is that through these discussions, I will attempt to make an overall assessment of the perceptions of ‘responsibility’/RI in nanotechnologies and its implications in the two cases of this study. Through these discussions I will also present a number of challenges related to governance practices that were identified in this study. The challenges include topics from common issues of lack of funding for EHS studies and lack of funding for R&D for small organisations, to new issues of tax code for nano-based products; regulation through stringent food legislations in Canada, to classical issues of risk perceptions associated with other emerging technologies like GMO and irradiation in food.

Centring on the perceptions of ‘responsibility’, regulation and markets of nanotechnologies as perceived through the lens of actors in the respective regions, this chapter will address the ‘responsible’ governance of nanotechnologies in the F&FP industries in two extremely different and oppositely diverse settings – India, a developing, OECD-interest country with limited or low regulatory standards; and Canada – a developed, OECD country considered to have very high regulatory standards. The chapter will introduce varieties in the notions of ‘responsibility’ in these two diverse regulatory settings and discuss how they apply to both countries, while simultaneously focusing on the differences and commonalities (see Table 8). This study contributes significantly to the understanding of the culture and progress towards RI within these countries (keeping in mind that these markets play a key role in globalization) and provides useful information into the growing trends of nanotechnologies in the F&FP sectors in emerging and developed economies.

In Chapter 3, the Conceptual Framework chapter, I provided three research questions - a key research question and sub-questions. In this chapter I will revisit my research questions, addressing my two sub-questions first:
(i) How is the ‘responsible’ development of nanotechnologies (for F&FP sectors) influenced by national regulation and governance regimes?

(ii) How is the ‘responsible’ development of nanotechnologies (for F&FP sectors) shaped by the normative framing of technology (and their interpretation of what it is to be responsible) in each region?”

Figure 25 and Figure 26 in Appendix 19 and Figure 27 and Figure 28 in Appendix 20, provides a diagrammatic representation of the categories under which these research questions are answered in each region. Following this, I will then address my main research question:

(iii) How do notions of ‘responsibility’ and regulation affect different geographies and markets for nanotechnology?”

7.1.3 Chapter sections

Using the scenarios in Table 7, I will begin by comparing the national regulatory and governance regimes in Canada and India in section 7.2. highlighting unique regulatory practices in Canada (through stringent regulations and stakeholder dialogues) and India (open innovation culture and labelling of nano-products). Though the focus of this study is governance rather than regulations, however, it was important to understand the regulatory structures of the two jurisdictions in order to capture formal regulatory settings and government effectiveness in the governance of nanotechnologies in the two regions. While comparing the two nations, I will also underline various commonalities such as government support through infrastructure and resources and interest in EHS/ELSI issues. This section will address my first research question: “How is the ‘responsible’ development of nanotechnologies (for F&FP sectors) influenced by national regulation and governance regimes?

Section 7.3, contributes to a comparative analysis of actors’ perceptions of ‘responsibility’/RI and answers my second research question: “How is the ‘responsible’ development of nanotechnologies (for F&FP sectors) shaped by the normative framing of technology (and their interpretation of what it is to be responsible) in each region?” Comparing the different notions of RI in Canada and India, I argue that the notions of ‘responsibility’ defer in each region and are based on their understanding of the technology. While discussing the shared and
common view of actors as to ‘who is responsible’ for the governance of nanotechnologies in F&FP, I will also discuss the rise of various intermediaries (e.g. NGOs and celebrities) as perceived to have an important role in the ‘responsible’ governance of nanotechnologies.

After addressing perceptions of regulation and responsibility in Sections 7.2 and 7.3 respectively, section 7.4 will provide an understanding of how existing governance institutions and perceptions of ‘responsibility’ affect the growth of markets of nanotechnologies in Canada and India. In doing so, it answers my third and main research question: “How do notions of ‘responsibility’ and regulation affect different geographies and markets for nanotechnology?”

In this section, I argue that the open innovation culture and R&D and commercialisation of nanotechnologies in government-led institutions have created an open market for the sale of nano-products in India. I further argue that collaborative networks and collaborations, such as the Mango Project between Canada and India, while setting a stage for ‘responsible’ practices, also provides a global market for future trade of nano-based products.

Finally, section 7.5, provides a summation of what is learnt from the discussions in this chapter and offers a summary of the varied notions of responsibility as a unique model for addressing RI in Canada and India.

7.2 National governance structures within Canada and India

This section addresses my first research question: “How is the ‘responsible’ development of nanotechnologies (for F&FP sectors) influenced by national regulation and governance regimes?

In the following sections, I will discuss the findings of my study by focusing on the role of the government in addressing RI as perceived through the lens of actors in Canada. I will begin by providing information on the R&D of nanotechnologies as a focus for both the GoC and the GoI. I will then discuss the availability of funding for R&D projects – specifically for public institutes - and highlight the challenges faced by private firms in India due to the lack of it. I will also provide examples of governance through collaboration networks that were identified within Canada and India and between the two regions. Following this, I will look at governance of R&D of nanotechnologies within these regions, focusing on stringent regulations and stakeholder involvement in public policy debates in Canada, and use of intermediaries and
labelling of products in India. While focusing on governance approaches I will also look at the challenges of regulating nanotechnologies within and across borders due to the lack of knowledge and skilled resources within Canada and India. Finally, I will conclude this section by looking at the EHS and ELSI research strategies within Canada and India.

7.2.1 Supporting domestic R&D and stimulating economic growth and development

From the findings in Chapters 5&6, it is clear that both Canada and India have realized the opportunities of nanotechnologies and are investing significant amounts of resources in the R&D of the technology. A common approach of strategic investments and collaborations to gain a competitive market over other nations was predominant in interviews. In Canada, nanotechnology was seen as a tool to propel economic growth while in India it is seen as a tool for socio-economic development of the region. In both jurisdictions, the State appears to play a predominant role in partnering with universities and public institutions by supporting projects through the provision of funding, infrastructure and other means of support. Many commercially viable products in F&FP are also under development at universities funded through various government agencies and public-private partnerships. This suggests that nanotechnologies are an important part of the national S&T agenda in Canada and India where both countries are gearing to enhance R&D in nanotechnologies, as it is seen as a potential for future trade opportunities. In a recent survey by OECD in twenty five countries similar views were found where nanotechnology was seen as having a role to play in industrial competitiveness and in addressing major economic and social challenges, including food security (OECD WPN 2013).

The GoC’s approval for the unrestricted use of cellulose nanocrystals (CNC) or NanoCrystalline Cellulose (NCC™) (ArboraNano 2012; ArboraNano 2014), much before even its neighbor, the U.S., also suggests that Canada is keen to gain a competitive advantage and keep ahead of the “waiting game” by establishing its position in the nanotech marketplace. Innovation is a key “competitive weapon” for governments and organisations around the world (Cooke 2002). Thus, these early incorporation and decision on nanocellulose shows Canada’s interest and perhaps priority in R&D of nanotechnologies.

In India, the initiatives for R&D of nanotechnologies are driven by the State as a means of solving some of the societal grand challenges. Though it appears that it is mostly driven by
commercial interest, linking such technology developments with the social priorities and goals of India is seen to be important in influencing the course for the economic development of India (TERI 2010a). The potential of nanotechnologies to significantly advance the living conditions of the underprivileged in developing/emerging economies was first elaborated by Salamanca-Buentello et al in 2005. At the time, it was highly disputed by many researchers (Foladori and Invernizzi 2005; Invernizzi and Foladori 2005) and some NGOs argued that nanotechnology will further create a ‘nano-divide’, a gap between the rich and the poor (ETC Group 2003a). However, the findings in this study point to various initiatives (e.g. nanosilver water filters, nano-packaging for mangoes) where the use of nanotechnologies has largely benefited the poor as envisaged by Salamanca-Buentello et al (2005).

While there has been extensive support from the government as elaborated by participants, this study found that collaborations between industry and public-funded institutes in India are limited and challenging (see Chapter 6, section 6.2.5.6). This means that commercialization of nano-based products from institutes is slow and limited, though there appears to be some effort by the GoI to promote technology transfer and commercialization for successful socio-economic growth. Research has shown that the rate of successful technology transfers in developing countries is 3-5%, while that in developed countries is 10-15% (Govindaraju 2010). Thus, many technologies tend to remain at an R&D level in institutes due to the weak link between research institutes and the industry (Sharon 2013, p.17). In order to take nanotechnologies to market, it would require the GoI to provide greater support in technology transfer and commercialization of new innovations, not only from public institutes but also those from smaller firms.

In contrast, in Canada, the funding structure by and large is based on a match-funding model, which encourages organisations to collaborate with universities and research institutes. This has led to many companies to collaborate with universities on nano-based F&FP projects as found in this study, which could, in future, enable easy transfer of the technology. Further, it appears that such joint ventures provide companies not only low-cost opportunities through pre-negotiated licensing terms, but also allows them to work on new technologies without being scrutinized or open about it. Moreover, many university-based research projects in F&FPN already have patents, and these partnerships with organisations are also expected to help determine the commercial potential of these university-developed technologies; as a
result, allowing nano-products a quicker entry into markets in future. It can also be suggested that such public schemes allow government and regulators to monitor nanotech research outcomes, whilst perhaps also regulate nanotech activities and processes by organisations within a safe environment. Shapiro and Willig have pointed out that “state ownership provides more information to regulators than private ownership” (Shapiro and Willig 1990) and thus helps reduce information asymmetries (Kirkpatrick and Parker 2004).

From these findings it can be concluded that despite the potential risks associated with nanotechnology, R&D in nanotechnologies has been well-financed and encouraged by both, the Canadian and Indian governments at universities and research institutes. In both scenarios, the fostering of public-private partnerships at universities in Canada, and support constraints in India could, in future, allow these governments to keep a check on firms (indirectly) on their activities in ‘responsibly’ developing nano-products, and therefore impede commercialization on a large scale, especially in a risk-averse country like Canada.

7.2.2 Introduction of standards and stringent policies to regulate nanotechnologies

The findings suggest that while Canada and India are very focused to R&D of nanotechnologies for commercial purposes, both jurisdictions do not have any specific regulations for nanotechnologies. These findings are consistent with other studies on Canada and other developed/OECD countries like the United States, Australia, New Zealand, and Japan, and non-OECD/emerging countries like China, where policies for nanotechnologies are still absent (Tachikawa 2012; Pelley and Saner 2009; Gergely et al. 2010).

Besides these parallel developments in Canada and India, there are many differences in institutional structures. For example, Canada currently depends on its stringent regulatory system to govern existing F&FPN (see Chapter 5, section 5.3.2). Safety issues are culturally sensitive in Canada and as a highly risk-averse country, Canada has very stringent policies in place to regulate F&FP products, including agriculture and novel foods. Another interesting finding was that approval processes for novel food products are long, extensive and rigorous and despite some novel materials having been approved in other OECD countries, these took up to ten years for approvals in Canada. For example, Phytosterol, which was approved in the
U.S. many years back has only been approved in Canada recently (Health Canada 2010). Canada was also the first country to ban acrylamide bisphenol A. Such severe actions highlight Canada’s stringent laws in F&FP. The situation of such stringent protocols and regulatory instruments as an interface between new technologies and safety of consumers are expected to provide governance mechanisms for future commercialisation of F&FPN.

However, these findings also suggest that the ability to commercialise innovation in F&FP in Canada is hindered by these stringent laws. This study found that such stringent legislations are forcing some companies to move research activities to the U.S. where economic policies are more flexible and there is a bigger market for nano-products (see Chapter 5, section 5.3.2). Patented technologies are also being licensed to companies in the U.S. This finding is consistent with an earlier study on nanotechnology patents in Canada, where it was found that 50% of the nanotechnology intellectual property (IP) developed by Canadian innovators were owned by foreign entities, one third of which were owned by American companies (Beaudry and Schiffauerova 2011). This suggests that Canada’s stringent laws, while regulating against risks often related to new technologies, are also driving away Canadian intellectual property to other territories that are more accepting of new technologies.

While there is wide consensus among the participants that the regulatory protocols in Canada for food are stringent (see Chapter 5, section 5.3.2), the common perceptions among many actors was that the regulations for nanotechnologies in Canada are still behind those in Europe (see Chapter 5, section 5.3.1). There were repeated references by actors of Europe’s rigid approach towards nano-regulations. Europe has been at the forefront in efforts to ensure the safe and ‘responsible’ development of nanotechnologies by addressing knowledge gaps, financing research on RI and by continuously upgrading existing regulatory frameworks to address the growing challenges of nanotechnology, especially in food. Canada’s existing regulations lack such specific regulations as the EU’s REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) enforced in 2007 (European Commission 2000) and the more recent regulation requiring obligatory labelling of nanomaterials in food by producers, until such time that the European Food Safety Authority (ESFA) is able to establish

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a specific risk assessment strategy. The absence of similar regulatory tools in Canada may be related to the finding from this study that in Canada, there is no strategy on regulation of F&FPN. These findings lead to suggestions that despite the notion that regulations for novel F&FP products are stringent in Canada, it is in comparison not as stringent as Europe. Canada controls certain novel products from getting into markets but has not as yet brought in any form of nano-regulation that directly regulates nanomaterials, which causes severe loopholes in regulation. The lack of substantive regulation may also be due to the proliferation of regulatory bodies at the provincial and federal levels which has resulted in a lack of clarity about roles and responsibilities. Additionally, there were consistent reverberations among participants about austerity programs and budgetary constraints (see Chapter 5, section 5.2.1), which may have resulted in a shortage of resources and further inhibited the establishment of a specific nano-regulatory body. Similar issues of lack of resources for regulatory action of nanotechnologies has been found to be prevalent in other jurisdictions (Tachikawa 2012, p.117).

Having said that, this study found that Canada’s regulatory policies are science-driven and in the absence of sufficient data on nanotechnologies, currently F&FPN is given the same regulatory consideration as any other novel food products and covered on a case-by-case basis. This approach is similar to the EU (European Commission 2012) and some other OECD countries that have indicated that the regulatory authority to address issues of nanotechnologies will be based on assessment made on a case-case basis (Falkner et al 2012). Moreover, Canada has great confidence in its existing protocols. Thus, the State is unwilling to take quick decisions on regulations of F&FPN and appears to be taking a very cautious approach in the regulation of nanotechnologies by closely watching the nano-regulatory. Nonetheless, modification of existing regulatory structures is a potential approach that is being considered in the near future. Additionally, further to interviews with participants in 2012 with regards to the review of materials in the DSL, in January 2015, Canada began review of 33 significant new activity (SNAs) orders and notices for nanomaterials in order to ensure that they are in line with existing policies and approaches. Another example is the incorporation of the CSA Z12885 for safety guidance at the workplace in Canada. Thus, there are continuous rescissions

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and amendments being made in Canada’s policies and approaches to nanomaterials, though these may be slow.

In contrast, in India, it was established that discussions for regulatory frameworks for risk assessments of nanotechnologies are limited and not given much focus in India. There emerged patterns of uncertainty among Indian government officials on the need to regulate nanotechnologies in India. Discussions with various actor groups showed reluctance on the part of regulatory officials to bring out any form of regulation too early, as they believe there are no nano-products in the market. Moreover, they justified their decision by pointing out the absence of regulation in other developed countries. Thus, the GoI appears not to be in a hurry to bring out any form of regulations. Instead, they appear to be playing a “waiting game”, as they await the establishment of a regulatory framework by the international community. These “waiting games” are driven by the force of potential promises of meeting grand challenges (Parandian et al. 2012) and therefore legitimize the absence of regulation as a substitute of promises of greater things to offer in future. Thus, the complacent attitude of the GoI in moving forward with hard regulations can be linked to the fear of hampering innovations as was also pointed out in a study on nanoethics in Europe, India and China (Fautz et al. 2014).

However, findings also indicate that both Canada and India are never the first to take the initiative to create new laws but appear to follow that taken by the U.S.A. Though there is a thinking among participants that Canada would not lead in setting regulations on nanotechnologies and would following the U.S. or the EU, this finding is in contradiction to existing steps taken by Canada in nano-regulations. Canada was one of the first countries in the world to come up with a definition of nanotechnology, and it is also the first country to approve nano-cellulose, much before the U.S. and EU. Canada is also leading in assessments of nanotoxicity in the ISO/OECD committees for nanotechnologies. Such incremental steps point to Canada’s competitive desire to establish its position in the global nanotech arena, while being cautious in making regulatory decisions too early.

### 7.2.3 Pressure from intermediaries for regulation

The presented findings (see Chapter 5, section 5.5.1) suggest that there is fear of CSOs/NGOs due to their growing pressure on industry to disclose their activities on nanotechnologies. Such demands from CSOs/NGOs to label products incorporating new technologies have deterred
companies from disclosing their activities. Furthermore, with GM foods still under scrutiny, and mounting pressures from intermediaries, there is also intense burden on the GoC to clarify its stance on nano-regulations. While, the findings do not suggest pressures for regulation from organisations, the Canadian government understands that in order to reap the benefits of its investments and encourage innovations in organisations, ‘intelligibility’ in nano-regulations are needed. It can be suggested that pressures for nano-regulation from CSOs/NGOs and the public have coerced the GoC to initiate various programmes that would lead to the establishment of sound regulations for nanotechnologies in Canada and regulatory oversight.

In India, however, there are no immediate pressures from CSOs/NGOs for regulation as there is greater focus on innovation for societal development. Infact, NGOs were seen to stimulate nanotechnologies use in rural regions in India (discussed in detail in section 7.3.3.1). Hence, it can be argued that an absence of such pressures for regulation also desists the GoI in taking action on nano-regulation, thus allowing an open environment for the private sector to carry out R&D and develop nano-products.

7.2.4 Labelling nano-products

Prevalent in the debate for ‘responsible’ development of nanotechnologies is the need for labelling of nano-based products (Renn and Roco 2006). As pointed out in the literature, a growing body of CSOs/NGOs are calling for labelling of nano-products (Falkner et al. 2009). However, labelling can be quite controversial especially in relation to new technologies. In the recent past, we have seen that calls to label GM foods in the U.S. was repeatedly rejected (Falkner et al. 2009). Similarly, labelling of nano-enabled products could affect its acceptability (or non-acceptability) in society (Gruère 2011; Chun 2009).

The presented findings show that labelling of nano-based products are perceived quite differently in Canada and India.

In India, this study found that while labelling was not mandatory, various nano-based products, such as formulations for agriculture, fishery and water filters, were openly labelled as ‘nano’ and sold in the market. This can suggest two things – first, that nanotechnology is well adopted in India, and second, that companies use the term as a buzzword to attract consumers into buying the products. Both, these inferences are only suggestions and would need further
investigation by investigating the notions of the Indian public. However, the ‘transparent’
labelling of products does reflect the difference in attitude towards perceptions of
nanotechnologies in India. On the other hand, it is interesting to note that while GM-related
products are required to have mandatory labelling of products in India (Sharma 2013), this is
not (as yet) the case for nano-based F&FP products, which have similar concerns of EHS and
ELS issues. This once again suggests that the GoI’s focus is on R&D of nanotechnologies and
about ‘catching-up’ rather than the risks of the technology.

In contrast, in Canada, products are not labelled, though findings from interviews show that
there are nano-based products in the market. Despite the recommendation of the Canadian
Institute for Environmental Law and Policy (CIELAP) for mandatory labelling of
nanomaterials in consumer products in a released report in 2008, Canada has not as yet
implemented mandatory labelling. There is consensus against labelling of nano-based F&FP
products among various actors in Canada (see Chapter 5, section 5.3.5.). Companies believe
that they will be penalised, whether they label products or do not label products that incorporate
nanomaterials. As in previous literature, participants also pointed out that consumers do not
possess the scientific ability to be able to make a true judgement on the safety of a product and
may perceive the nano product as risky. Thus, labelling is seen by some actors to be a weak
form of regulation, which can demonize products. Moreover, actors maintained that labelling
can also be costly and could be passed on to the consumers, though previous research on
consumers response to labelling has shown strong positive reaction, especially by those in the
West, where consumers demanding labelling of nanofood products were willing to pay a
premium price for labelling (Brown and Kuzma 2013). While these arguments do provide a
legitimised reason for not labelling of nano-based products, labelling conforms to the principle
of the consumer’s right to know (Miller and Senjen 2008a, p.3) and is essential for
transparency. However, there is also a danger that labelling could transfer the responsibility to
the low-knowledge society/consumers (Throne-Holst and Rip 2011), and therefore escape
responsibility by both regulators and innovators. Labels could also result in unintended
perceptions (Siegrist 2008, p.606) similar to that seen for the precautionary principle where
information about precautionary measures was found to escalate perceptions of risks among
the public (Wiedemann and Schütz 2005). Labelling of nano-based products in Canada,

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63 During this study a company in the cosmetic industry did have a voluntary ‘no nano’ label on their sunscreen
product (see Appendix 2)
however, is most likely to be driven by the outcomes of GMO labelling campaigns, which so far has been unsuccessful.

Thus, participant views are played out differently in labelling of products. While in Canada, participants from organisations refrain from labelling nano-based products, those in India were already openly labelling these. The differences in the ways that nano-based products are labelled (in India) and not labelled (in Canada) also suggests, that there is a vast difference in the way nanotechnologies are perceived in Canada and India. It appears that there is less public acceptability of nanotechnologies in Canada (whether through stringent laws, consumer (non)acceptability or NGO scrutiny), where companies are forced to refrain from labelling products; compared to India where companies openly label products (due to endorsement by government on other nano-based products in public institutions and absence of public backlash). This however, would require further and deeper investigation.

7.2.5 International co-operation on addressing policy gaps

Canada is collaborating quite closely with its global partners on the potential utilisation and impacts of nanotechnology (e.g. ISO, OECD, RCC). Their current efforts are part of coordinated activities to work in conjunction with international bodies so that there is an approach that is being taken together with different governments and they do not face the problems that are currently occurring with the biotechnology industry. Such cooperation also ensures Canada’s effective inputs and contributions in the debates on nanotechnologies on an international level. Moreover, by working closely with international committees and governments on standards and policies, Canada will in future be able to map its national standards and regulatory frameworks to those proposed globally. Consequently, Canada’s participation in such international policy-related activities allows them not only to keep abreast of the latest developments in regulations of nanotechnologies, but also helps them make other internal decisions on regulation of nanomaterials. For example, Canada’s guidance for safety at the workplace, the CSA Z12885, is a revision of the ISO Z12885. Such national initiatives and international participation towards the harmonisation of standards and regulations also reflects Canada’s lean towards safety practices and considerations.

However, while such participations are essential for the ‘responsible’ development of nanotechnologies, formation of agreed standards can take a long time, where standards are
often developed after products have entered markets (Which? 2009). Thus, due to these ‘delays’ and no international consensus on the regulatory framework for nanotechnologies, and with potential markets for nano-products growing, Canada is seen to be funding various national initiatives, such as that undertaken by the Canadian Standards Association, to address regulatory gaps in nanotechnologies. Canada appears also to be involved in initiating various programmes in developing frameworks for R&D in nanotechnologies. In October 2011, Canada established a definition for nanotechnologies, ahead of most other developed nations. As per interviews in this study, Canada’s main regulatory bodies, HC, EC and the CFIA, are also working on regulatory frameworks for nanotechnologies in F&FP. All these initiatives reflect Canada’s growing readiness to govern nanotechnologies more effectively.

India on the other hand, though a member of the ISO and OECD committee, is not as active a participant in international debates. This was evident from findings with Canadian participants involved in these international regulatory committees. While participants in India did point out that they participate in the ISO committee internationally, discussions with Canadian participants found that representatives from India were rarely present at committee meetings. A review of the literature shows that India is clearly absent in many initiatives led by the OECD WPN (OECD WPN 2011; OECD 2010a). For example, between 2012-2013, WPN sought inputs from member countries on their national/regional government policy and/or national/regional research programmes supporting the ‘responsible’ development of nanotechnology (OECD WPN 2013). While Canada and such emerging countries like China and South Africa participated in this initiative, India was clearly absent. Similarly, in a survey on the “Regulatory Frameworks for Nanotechnology in Food and Medical Products” India was not a participant. This can suggest an indifference on the part of the GoI towards such initiatives.

7.2.6 Focus on stakeholder participation in policy debates

Establishment of a “participatory nanotechnology assessment network” which involves the inclusion and feedback of all the stakeholders, including nano-experts, organisations and public representative groups, is essential for the ‘responsible’ development of nanotechnologies (Roco et al. 2011, p.3571). It is essential for addressing significant gaps that exist between
researcher community groups, researcher and manufacturers, industries, regulatory agencies, voluntary and intermediary groups, media and the general public. (Roco et al. 2011, p.3568).

In Canada, the State endeavours to create a discursive environment on the issues of nanotechnologies through the inclusion of various stakeholders in nanotech policy debates (see Chapter 5, section.5.3.3). Thus, socio-technical discourses play a key role in governance, where a web of interlinking actors are involved in discursive conversations on the ‘responsible’ development of nanotechnologies. Such deliberations in nanotechnologies have been developed out of the public backlash that occurred against GM foods (Rogers-Brown et al. 2011, p.158), as also pointed out by many respondents. The involvement and deliberation amongst societal actors at an early stage of the innovation process helps avoid concerns in the future and therefore contributes to more acceptable and sustainable outcomes for society (Kupper 2014). Canada’s policy debates involve a heterogeneous group of powerful actors with varied roles. Those advising government in these policy debates are seen to wear different hats. For example, expert scientists and lawyers at universities were also seen to have additional roles in local and international policy-making committees and government-led agencies where their feedback is used in policy-making decisions. These policy debates also involve public representative groups and NGOs, and representatives from industry. As experts and non-experts in nanotechnology their presence helps to influence policy debates both, nationally and internationally.

The participation of these various stakeholders and actors in decision-making processes is necessary for public acceptance of nanotechnology (von Schomberg 2013). Similar consultations of stakeholders have been seen in the EU (NanoKommission 2009) and the U.S. (Schaper-Rinkel 2013). For example, Germany’s NanoKommission initiative take into perspective opinions from a wide group of non-governmental actors for policy recommendations and have included representatives from academic, CSOs and industry. It can be anticipated that the inclusion of these CSOs/NGOs will help appease major activism where the regulatory and political debates on nanotechnologies have not, as yet, had major backlash as compared to GM when stakeholders were excluded in similar debates.

However, the presented findings (see Chapter 5, section 5.3.3.1) show that the industry in Canada is often given precedence in such meetings as they are seen to bring innovation to market and thus help enhance the economy of Canada. Such approaches of “regulatory capture” have been highlighted in previous literature where high-stake interest groups have resorted to
influence policy or regulatory decisions in order to gain policy outcomes that they prefer (Jalilian et al. 2007; Stigler 1971). This reveals firms’ growing power in influencing public policy (Shaffer 1995). These findings suggest that despite the ‘display’ of inclusion of various stakeholders in policy debates, firms are given added consideration due to their ability to provide a competitive edge for Canada. This finding reiterates Canada’s focus towards enhancing economic goals. It may also suggest that these stakeholder debates are used as a ‘screen’ to help minimize hostility towards the issues of nanotechnologies where opponents are open to voice their opinions and proponents are able to respond to their criticisms and neutralize the issues.

Conversely, in India, findings show such institutionalised responsibility debates and structures are very limited, though not entirely absent. This shows a clear lack of emphasis on risk-related issues and debates on nanotechnologies. Both the empirical data from this study and literature show that public debate and knowledge around EHS issues of nanotechnologies appear to be limited in India (TERI 2010a). Where present these debates in government panels on nano risks had minimal participation of external actors and are often overrun by promises of nanotechnologies and what it could do for the Indian subcontinent, especially in the agricultural sector which covers 60.5% of land in India. This study found that while scientists, regulators and participants from large organizations, are invited on policy panels in India, the ‘bad’ NGOs/CSOs (especially those against emerging technologies) are often excluded from such debates. This could suggest that there is an intention by the GoI to avoid any untoward controversy or attention over this emerging technology, which has not (as yet) gained much attention/momentum in public and EHS debates as compared to the West. Furthermore, this study found that in areas where the debates involved nanotechnologies in agriculture, a particularly large firm was also involved in working on regulations with the government. While the participation from firms in such debates are essential, having companies play a major role in nano-regulations can limit other important views and opinions (Wetmore and Posner 2009), which are essential to the debates on nanotechnologies. It can also create issues of transparency in the ‘responsible’ development of nanotechnologies.
7.2.7 Regulating at the border

One of the major challenges of governance of nano-based products is the passage of goods, especially food (and beverages), across borders with differing regulatory settings.

Canada recently enhanced its food law, which provides CFIA greater powers to monitor its borders by holding importers accountable for the safety of food products entering Canada’s markets. By placing responsibility on the manufacturers through the recent Bill S-11, Safe Food for Canadians Act, it is expected that there will be greater responsibility from the importers in ensuring that food products imported by them are safe and have approved materials. It is expected that through these efficient border procedures and controls importers would be wary of importing such products that incorporate nanomaterials from their suppliers if these are not approved. This form of regulation creates a legal framework under which companies are obliged to manufacture, export or import materials and products only if they are safe. Such effective risk-based techniques will enable the GoC to control cross border movements of goods more efficiently, allowing them to put greater responsibility on the importer that knows what is in the products.

However, while this new Act is expected to control the entry of nanofood products through the Canadian borders to some extent, there is a danger that, first, with limited technical resources (capability and instrument), the importers and border control staff may not have the capability to identify the presence of nanomaterials in products as nanomaterials can go undetected in standard toxicological tests (Maynard 2012, p.4). Second, a lack of cooperation between various government agencies, organisations and the scientific community, essentially a dispersed system with overlapping responsibilities between agencies can create regulatory confusion, allowing unregulated nanofood and packaging products entry into the market.

In 2008, a research carried out by Senik D.R. & Associates Inc. found that 70% of nano-products that entered Canada came in through the Canada-U.S. porous borders (Senik D.R. & Associates Inc. 2007), where the U.S. is Canada’s main trading partner. With the proliferation of nano-products from the U.S., the recent RCC Joint Action Plan initiated by Canada is expected to provide an important step to enhanced regulatory cooperation between Canada and the U.S. towards the governance of nano-goods. However, while the RCC initiative will enable Canada to develop joint approaches and better align the regulatory environment for
nanotechnologies and reduce risks through shared information, border protection will still be a challenging issue for Canada where nano-based products can easily enter Canada through purchases made over the internet. The easy online purchase of nanomaterials by an NGO in this study (see Chapter 5, section 5.3.6) reflects one of the many loopholes in the governance of nanotechnologies.

7.2.8 Analogy between nanotechnology and GM foods

The potentials of such technologies as nanotechnologies cannot be realised by just supporting the technology and R&D. All technologies, including emerging technologies, like nanotechnologies, require a governance approach, where the broader implications, such as the societal and ethical issues, are addressed.

The empirical evidence suggests that the framing of how innovation processes develop in both regions is based on observations of different crises and catastrophes that have occurred in the past (e.g. GM foods/biotechnology/irradiation food). In both, India (see Chapter 6, section 6.2.5.1.) and Canada (see Chapter 5, section 5.3.4.3), parallels were constantly drawn to GM foods/biotechnology and the lessons learnt when discussing risks of nanotechnologies. This points to a similarity in literature, which shows that attitudes towards nanotechnology are similar to other emerging technologies, like biotechnology/GMO (Parr 2005; Leinonen and Kivisaari 2010; D'Silva et al. 2012; Friedman and Egolf 2005), raising similar concerns of health and safety. While there are several criticisms by various scholars where a direct comparison of the two technologies has been considered of “limited value” (Kearnes et al. 2006) and which needs “to be employed advisedly” (Sandler 2006), the findings from this study suggest that the GMO experience is continuing to shape political and regulatory debates around nanotechnologies and forms an essential component for discussing ‘responsibility’ in nanotechnologies.

As well as having profound new and transformative benefits in the food and agricultural sectors, both nanotechnologies and GMO are argued to be associated with potential health and safety issues. The environmental, social, and ethical concerns continue to dominate public debates surrounding GM technology (Ervin and Welsh 2006; Carr and Levidow 2000; Cotter et al. 2015) and are a growing debate in public discourses on nanotechnologies. Whilst some potential risks with regards to environment, health and safety relating to nanotechnologies are
completely new, many debates surrounding nanotechnologies are familiar territory and portray similar GM-style backlash and public debates. For example, the discussions on a ‘nanotech-moratorium’ (ETC Group 2003b; Illuminato 2014) is analogous to the ‘GMO-moratorium’ (Wiek et al. 2008; Rogers-Brown et al. 2011). Many of the same critical issues are also being raised by the same network of actors and social groups who mobilised previous GMO controversies (Miller and Senjen 2008; Nelkin 1995). Nelkin (1995) terms this as “discursive linkage”.

Studies have also shown that the perceptions of risk and hazards (and benefit) of nanotechnologies are a result of public perception of GM relating to unknown environmental and health risks, lack of evidence of real and actual benefits, concerns about “playing God” and tampering with nature (and naturalness of food) and the ecosystem, distrust and suspicion around the food industry and their power, and lack of effective government oversight. (Rogers-Brown et al. 2011, p.160). These similarities in the perceptions and attitudes of the public towards nanotechnologies and GMO have largely been negative in developed countries (particularly in the EU and the UK) and positive in developing countries (such as in India and China) (Krishna and Qaim 2008; Huang et al. 2006), which has also been reflected in this study. Rogers-Brown et al. (2011) point out that references to GM depicts the ongoing social issues around food that are of much concern to the public (p.160). The potential of drastic effects of nanomaterials and their interventions in the human body, including those causing deaths (Song et al. 2009; Song et al. 2011), has also been linked to a similar case of the death of Jesse Gelsinger in 1999 due to negative reactions from a somatic gene therapy trial (Wilson 2010).

The consumer concerns and risk perceptions of GMO have driven important biotechnology policies in developed countries (Moon and Balasubramanian 2004). For example, stringent European regulation did not permit GM crops to be grown or imported by any European country and even called for an “informal moratorium”, despite the technology showing no signs of health and environment hazards when used in crops and consumed around the world (Renn and Walker 2008). Similarly, there have been ongoing debates and updates on policy issues for use of novel nanomaterials in nanofood in the EU.

Despite there being conflicting evidences on the risks of these technologies, GM foods is already grown or sold in many countries around the world whereas food products of nanotechnologies are restricted or not openly sold in the market. There is distrust among people whether GM foods or nanofoods can actually benefit poorer countries or create a divide.
Nanotechnologies encompass a wider range of science and engineering approaches than biotechnology/GMO, and it is expected that its applications will be wide and varied over time, which makes it more complex to regulate.

Despite the technical differences of nanotechnologies and GMO and the novelty of the former technology, there are warnings that nanotechnology is likely to trigger a public reaction similar to that of GM crops (House of Lords 2010a, p.8) where risk debates have out-weighed the benefits of the technology. While some believe that the likelihood of a GMO-type backlash is overstated (Sandler 2006, p.57), failing to act on the public concerns and potential risks would likely turn nanotechnologies into the “Frankenfood” controversy that has been linked to GM foods (Swierstra and Rip 2007; Jotterand 2008; Marchant and Sylvester 2006). However, early studies on perceptions have reported that nanotechnologies are perceived as being less risky and more beneficial than GMO (Kuzma et al. 2008, p.1087). Further, public awareness of GM foods is greater than that of nanotechnologies especially in developed countries due to extensive media coverage and public backlash unlike nanotechnologies where awareness of the technology among people is low (Satterfield et al. 2009, p.753) and there appears to be less resentment in society towards the technology. This is because GM foods has been in the public domain for some time and people may have already formed certain attitudes and judgements toward GM foods whereas it is still fluid for nanotechnologies (Siegrist 2008).

The similarity in the issues (as well as benefits) relating to GM provide new approaches to dealing with new path-breaking technologies like nanotechnologies. There are many lessons that can be learnt from the GMO controversy. For example, much of the GM controversies came about due to the lack of communication on the part of scientists and regulators when the public and consumer representative groups’ concerns on the potential risks of GMO were largely ignored (Roco and Bainbridge 2001, p.33). The failure to include the public early on over biotechnology/GM debates led to various backlash due to suspicion and misleading information and regulatory problems (Mehta 2004). In learning from this experience, various stakeholders (including civil organisations) are now being engaged (upstream public engagement) in public debates and risk dialogues during policy-making of nanotechnologies, which is expected to avert the problems as those seen in GM foods. This was also seen in this study as discussed in sections 7.2.6 and 7.3.3.1.

There is also a similarity in the regulatory framework in conditions of uncertainty. Like GMO, there are continuous calls for regulation through labelling of nanofood products. However,
unlike GM foods where labelling laws were introduced in the EU but still remains controversial in the US, there is not, as yet, mandatory labelling of nanofood products, raising transparency concerns and the ‘right to know’ debates that are also echoed in GMO labelling debates.

GM foods have a unique place in risk governance of technological innovations as they were the first to be regulated under the precautionary principle (Renn and Walker 2008). The precautionary principle has also come to form part of a regulatory framework for R&D of nanotechnologies. Thus, the GMO experience has been prominent in motivating the scientific community, regulators and the industry to address the social and ethical dilemmas of nanotechnologies.

Many nanoscientists have emphasized that ignoring the potential dangers of nanomaterials is precisely what has led to major problems of acceptability of GMO foods. Learning from these past experiences, these scientists are vocally calling for safety and toxicity tests on nanomaterials. Thus, GMO has set an example and precedent to acknowledge and research the potential hazards of nanotechnologies.

7.2.9 Focusing on issues of EHS and ELSA

While the notions of past experiences from GMO were prevalent in discussions, the study found that in both jurisdictions, there is emerging consensus on the risks of nanotechnologies and the need to address it (see Chapter 5, sections 5.3.4 and Chapter 6, section 6.2.6). Scientists from both Canada and India were well aware of the EHS and ELSI aspects of nanotechnologies and the problems of similar issues from the GMO experience. Interestingly, the findings from this study showed that Indian government officials and scientists/innovators, too, showed much interest and knowledge in the EHS and ELSI areas of nanotechnologies. This finding is consistent with a similar study that investigated the perceptions of nanoethics in Indian scientists (Patra et al. 2010). A plausible explanation for this may be that many independent researchers who had completed their studies or had done some research projects in nanotechnologies in developed countries had gained awareness of the issues and were thus very conscious of the need to address the risks of nanotechnologies. Various public research institutes are also involved in programmes on nanotoxicity. However, while this study found various efforts being made to generate more focus on risks and risk assessments of nanotechnologies through these programmes, they are limited. Nevertheless, this reflects the growing knowledge of actors and their attention to address risks of nanotechnologies.
Funding agencies in Canada also play an important role in influencing the ‘responsible’ development of nanotechnologies in India. In Canada, funding agencies have a mandate to include biosafety tests as a key component in their criteria for distribution of grants. For example, as part of the process of distribution of grants, this study found that in the case of the mango nano-film packaging project, biosafety tests were set as criteria for funding by IDRC. Such criteria for biosafety tests in competitive grant applications highlight Canada’s early intervention and acknowledgement for addressing the ‘responsible’ development of nanotechnologies which will help to shape and steer the introduction of nanomaterials and products into Canadian markets, from such markets as India, as well as export products and materials from Canada. A review of secondary research also showed that many workshops pertaining to debates on nanosafety issues in India were often sponsored by Canadian agencies. For example, in January 2010, the S&T group at The Energy and Resources Institute (TERI), through the support of IDRC organised a one day workshop on the “Issues of Risk in the Regulation of Nanotechnology” (TERI 2010b). The workshop involved debates and discussions on the EHS and ELSI aspects of nanotechnologies through the involvement of over thirty actors, including scientists, toxicologists, social scientists, entrepreneurs, policy-makers, regulators and non-governmental civil society organisations. These scenarios suggest interventions of developed countries, like Canada, in addressing the ‘responsible’ development of nanotechnologies in developing countries, like India. I argue that such interventions by Canada are instrumental in transferring high ‘responsibility’ in India.

The involvement of India in the ISO and OECD debates also reflects their keenness to abide by global standards though as pointed out earlier there was limited participation by India in international debates. However, certain ISO guidelines are already being adopted in India as was seen in a case at CIRCOT, where researchers are working to satisfy conditions set by their partners pertaining to ISO standards for nanotechnologies. All these initiatives are positive indications of efforts being made by India in addressing the EHS and ELSI aspects of nanotechnologies.

Furthermore, India has successfully developed a voluntary guideline for the safe handling of nanotechnologies at the workplace. Few countries (e.g. Japan) have developed such guidelines
for the safe handling of nanomaterials (Falkner and Jaspers 2012). This highlights India’s early acknowledgement and attention in such issues of nano-safety.

However, despite these growing initiatives and research projects on risks in various public institutes in India, the GoI’s response to risk, although emerging, appears to be very slow.

The findings from this study show that there are no ‘official’ research strategy for the EHS issues of nanotechnologies, especially in F&FP, in either Canada or India, though the study found that Canada is highly engaged in the ‘responsible’ development of nanotechnologies. Various government bodies and institutes have been set up in specific provinces of Québec and Alberta in Canada to specifically address the EHS and ELSI aspects of nanomaterials. These have been funded by both the federal and provincial governments. Such initiatives point towards a focus on RI as provinces take the lead in responsibility for the safe development, use and commercialisation of nanotechnologies.

In Canada, ‘responsibility’ is also embedded within current institutional practices. For example, the research ethics boards (that are set up at every university) are required to examine all university research projects for potential negative effect before any funding is approved by the government. Thus, allocation of funding is based on a ‘score-card’ of ‘responsible’ practices, such as safety assessments, which are set as criteria for funding. These initiatives elaborate Canada’s attention in addressing EHS and ELSI aspects of nanotechnologies by the government early on. The GoC’s early intervention in nanotechnology risk assessment studies also indicate that policy is based on scientific evidence, and results of these assessments are likely to be used for future policy design and implementation. However, much of the funding is ad-hoc and for limited-term projects, which may not be able to fully address the issues of nanotechnologies within an entire lifecycle of a product.

This study also found a severe lack of risk funding in both Canada and India. In Canada, austerity measures taken by the Harper government threatened to cut corners in the areas of EHS and ELSI (see Chapter 5, section 5.3.4.2.). In India, the lack of sufficient funding from GoI towards safety issues often led to researchers being unable to carry out research on safety issues of nanotechnologies. Smaller companies lack the resources and infrastructure to carry out safety assessments of nanotechnology. Many of the researchers/scientists, especially in public institutes in India, were unable to carry out safety tests because they had limited, short-
term funding from the government and priority was always given to R&D and commercialisation of nanotechnologies. This indicates that the strategic policies and actions for risk governance of nanotechnologies are still immature in India, although there is clear indication and acknowledgement by governance actors that this is slowly being developed and likely to be given a priority in the near future. A study by Renn and Roco (2006) on risk governance of nanotechnologies showed similar results where various countries were identified to have underdeveloped risk governance but had plans to give it more focus (p. 89). However, such limitations in funding and delays in risk assessments can lead to untested products being placed in the market, which could cause detrimental incidents. Already from this study we have found that various products have already made its way into the market. Larger firms are also often concerned that such adverse incidences caused due to the insufficient capacity of smaller firms to carry out risk assessments, can lead to a demonization of the technology and exaggeration by the media (de Bakker et al. 2014). However, the lack of engagement of actors for the risk assessment and management of nanotechnologies is not just an issue of deficiency of funds, but also the gap that exists in the current institutional frameworks, where there is greater focus on promotion of nanotechnology (TERI 2009b, p.43).

From the above, we find that attention towards the ‘responsible’ development of nanotechnologies does exist within the two jurisdictions, but funding is lacking. Such gross imbalance with regards to budgets for R&D and commercialisation of nanotechnologies and those for research towards EHS issues have also been noted in previous literature (ETUC 2008). The relative low share of funding towards risks research on nanomaterials suggests that there will continue to be a gap in accepted protocols for assessing risks of nanomaterials in nanofood, worldwide (Gruère et al. 2011). Furthermore, much of the research on risks of nanomaterials is focused on packaging, and not on food (Chau et al. 2007, p.276), as nano-packaging is expected to penetrate the market faster than food. This focus on food packaging could further create a bigger gap in assessing risks in food products in Canada and India.

Previous studies have pointed out the need for countries to collaborate on nanotoxicity for harmonization of data. However, some of the issues raised by participants in the scientific community in India reflect concerns with regards to the non-sharing of data by the international scientific community. Many scientists in India argued that the international community completely ignored their requests to share data on nanotoxicity. This suggests a lack of co-
operation and co-ordination between OECD and non-OECD scientists. However, this study found interesting cases of collaborations that involve EHS research, where India was seen to be collaborating with various OECD countries on nanotoxicity projects. Many of these collaborative projects entailed research on nanotoxicity and biosafety tests with developed countries. Not surprisingly, the research found that many of these projects that incorporate tests on animals are being sent to India because animal testing is restricted in some developed countries. While on the one hand, such collaborative projects highlight the trust in the calibre of researchers to conduct safety tests in India, on the other hand it points to the exploitation of the low Indian regulatory system by developed countries.

7.3 Understanding notions of responsibility/RI

In this section, I will discuss perceptions of ‘responsibility’ of nanotechnologies as perceived by actors in the nanotech food chain, within Canada and India. First, I discuss the notions of ‘responsibility’ among actors in Canada and India, where I find major differences in the notions of ‘responsibility’ in the two regions. I then discuss who the actors perceive is ‘responsible’ for the governance of nanotechnologies, which provides a common view in Canada and India. I also discuss the unique roles of intermediaries, including CSOs/NGOs and retailers/industry in the governance of nanotechnologies. This section contributes to an analysis of actors’ perceptions of ‘responsibility’/RI through a variety of interpretations, and therefore answers my research question: “How is the ‘responsible’ development of nanotechnologies (for F&FP sectors) shaped by the normative framing of technology (and their interpretation of what it is to be responsible) in each region?”

7.3.1 Perceptions of responsibility/RI

Canada has seen many food safety disasters where public debates have reached high levels of discussions. Hence, safety of products is a huge priority and paramount among perceptions of actors. This study found that the notions of ‘responsibility’/RI among the participating actors in Canada entailed the development of innovative products for health and nutrition, sustainability and safety of products. Regulations and standards were also seen as important instruments in overseeing responsibility, where such instruments are used to identify potential risks and to ensure that there is a process of investigation that is carried out. Public acceptance and support was also an important highlight among various actor groups in their perceptions.
of ‘responsibility’/RI. Thus, the framings of responsibility focused on established norms of best practices, including in the laboratory, research integrity, ethical compliance, concentration on safety, sustainable products and consumer acceptability.

Whilst addressing risks of nanotechnologies were predominant in discourses in Canada, a developed country, in India it opened up the inclusion of broader ideas than risks – that of ‘responsibility’ through innovation that benefits the lower pyramid of society. This study found an alternative and unique perspective on ‘responsibility’ in India where there is strong emphasis on societal values, which is linked to participants understanding of what it means to be ‘responsible’. This was evident from actors’ perspectives on RI where addressing the grand challenges, such as alleviating poverty, providing clean drinking water, increasing income for the poorer sections of society, and generally improving the livelihood of poor people using such emerging technologies as nanotechnologies, was seen as ‘responsible’. Thus, the use of nanotechnology was all about maximizing benefits for the society, specifically the poor, and for the social and economic development of the region. Participants also emphasized on the avoidance of potential negative impacts from the creation of novel nano-products. This theme was dominant in almost all the participants which also provided nano-innovators a motive for development of nano-based products in India.

Such notions of responsibility in India appear to be similar to that defined by the National Research Council in the U.S. where the ‘responsible’ development of nanotechnology is “a commitment to develop and use technology to help meet the most pressing human and societal needs, while making every reasonable effort to anticipate and mitigate adverse implications or unintended consequences” (US National Research Council 2006. p.73). These similarities in notions of responsibility point to the emergence of an understanding of responsibility pertaining to nanotechnologies in a non-OECD country as perceived by an OECD country. As such, these similarities offer an overarching framing of the governance of nanotechnology as fundamentally similar to that of an OECD country. Here, the framing of responsibility is seen as a necessity for commercialization of nanotechnologies for the benefit of the poor. The use of nanotechnologies among participants in India is seen as being completely legitimate as their notion of ‘responsibility’ means that this is helping to meet some of the grand challenges of society. Thus, it can be concluded that the generally positive perception towards nanotechnologies in F&FPA in India stems from more urgent needs for food security,
alleviation of poverty and availability of clean drinking water. A study conducted on consumer acceptance of GM foods in developing economies found similar results where positive perception towards GM foods in developing nations advanced from their need for food availability and nutritional value (Curtis et al. 2004). Still, risks need to be continuously assessed and managed.

While, there is a common view by the West that the regulatory system in India is low, this was strongly disputed by some participants, who pointed out that developed and highly regulated countries like Canada and the U.S. are rampantly using such emerging technologies like GMO in food (see Chapter 6, section 6.3.2) whereas GMO testing in agriculture is restricted in India. This comparison suggests a thinking among participants in India that India does have the ability to bring in ‘responsibility’ through ‘responsible’ regulation.

Notions of ‘responsibility’ are also understood as ‘following international standards’, where various biosafety tests on nanomaterials are carried out in international territories, and meet local and international regulatory requirements and certifications set by regulatory agencies such as the FDA and OMRI in the US, and APEDA and IndoCert certification in India (see Chapter 6, sections 6.2.5.7 and 6.4.1.1). The use of such third party certifications, which can attest a minimal transparent and verifiable practice, will be crucial for ‘responsible’ development, though these would need to demonstrate ethical considerations and not just technical safety issues (von Schomberg 2013). It must also be noted that while organic products are formally certified and labelled in developed countries like the EU and the United States (Thompson 1998; Thøgersen 2010), in developing countries, such as India, organic vegetables and fruits are seldom certified, and purchases are primarily made on trust relationships between the vendor and the buyer in traditional markets (Krishna and Qaim 2008, p.239). This can create a further gap in regulating products that are placed in the market without properly being physically certified.

The findings also showed that in India, the safety of nano-products was legitimized by participants through the use of “natural” bio-based nanomaterials, which have a GRAS status. In Canada, biodegradable nanocellulose was approved based on similar notions of safety and naturalness. ‘Natural’ is often used to connote positive aspects (Rozin 2005; Duncan 2011b), a reason why many companies resort to the word ‘natural’ on their products and advertisements.
Psychologically humans often have a preference for natural and less-processed foods (Rozin et al. 2004; Rogers-Brown et al. 2011) and studies on other new technologies have shown low motivation to consume altered foods, such as GM foods, even if clear benefits are outlined to consumers (Cox et al. 2004). We have seen that the genetic modification of food has led to various irrational consequences and backlashes, especially in the EU and more recently in the U.S. This is because consumers tend to have an emotional connection with food (Duncan 2011b) and food produced through novel processes are often perceived as unsafe, distasteful and unnatural by consumers (Grantham 2007). People tend to have more confidence in purchasing food that is produced naturally, rather than those that incorporate new food technologies (Huotilainen and Tuorila 2005). A study by Tenulbt et al (2004) found that the more a product is seen as natural, the less acceptable a (genetically) modified version of that product will be. Such perceptions of naturalness has also been found to influence perceptions of nano-based foods (Siegrist et al. 2007, p.465). For example, respondents in a study that deemed naturalness of food as important were found to have more risks associated with nanotechnologies, than those who gave less importance to naturalness (Siegrist 2008).

Naturalness is also related primarily by the process by which a product is prepared rather than in its actual content (Rozin 2005). For instance, the selective breeding of animals or plants over years resulting in drastically different genomes from that of its ancestral starting materials, is considered more natural than GMOs that have a single gene replacement (Duncan 2011b; Rozin 2005). This perception is mainly attributed to the fear of the consequences of ‘tampering with nature’ at the molecular level, which is less accepted morally, especially if the perceived unnatural ingredient is expected to be ingested (Siegrist 2008; Sjöberg 2000). Hence, even if modified and artificial products are shown to be as healthy as natural products, most people that have a “natural preference” for natural products would be unwilling to accept modified products (Rozin et al 2004). Similarly, despite clearly outlined benefits for nanotechnologies, consumers may be unwilling to try a new nano-product if this product was perceived as unnatural or less natural as compared to a nano-free product (Siegrist et al. 2009).
These past studies suggest that the importance of perceived naturalness is a vital factor in enabling social acceptability of nanotechnologies. This may explain why actors in this study stress on the term “natural” and why companies in Canada are disinclined to disclose use of nanotechnologies on their products for fear of branding it ‘unnatural’ as has been the case with GM foods.

The lean towards naturalness perhaps also explains why respondents believe that nanofood packaging is more likely to be accepted by consumers than nanofoods which are ingested, because packaging of food is often composed of unnatural materials other than nanomaterials (Siegrist et al. 2008).

Thus, natural versus engineered nanomaterials is a crucial aspect of acceptability of nanotechnologies (Rozin 2005; Rozin 2006). This does not mean that perceptions of ‘unnaturalness’ alone will result in the public rejecting a food technology. There are other factors of trust (or distrust) in regulation and effective labelling which are also essential when it comes to acceptability of food technology (Frewer et al. 2011). While differences in risk and benefit perceptions may shape consumer attitude to new food technologies, trust in government and (food) industry are important influencers of acceptability of food technology too (Siegrist et al. 2007; Siegrist 2008; Frewer et al. 2011). There is already public scepticism about how much industry and regulators can be relied upon to be transparent about uncertainties of nanotechnologies and whether they can manage them (Groves and Stokes 2011). This distrust can fatally undermine the legitimacy of nano F&FP products.

Further, although many nano-sized particles are known to occur naturally in nature (e.g. lactose and whey proteins in milk) (Buzby 2010; Chun 2009), a lack of standardised definition for nanomaterials makes it difficult to ascertain what constitutes naturally-occurring nanomaterials (Which? 2009) and what is safe. For example, conventional materials such as lipid droplets, which could form nano-emulsions or micelle systems (Weiss et al. 2006), are not characterised as nanomaterials by some experts. Further, some of the manufactured materials have been in use for over fifty years (Sekhon 2010, p.5), hence classifying and defining such nanomaterials as novel can be complex.

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64 In addition to perceived benefits, perceived risks, quality, price, values and cultural norms.
Participants from the scientific community in India further argued that very small and negligible quantities of nanomaterials are ‘safe’ to use. Any ideas of the negative effects on health and environment due to the small size of nanotechnologies are dismissed by these participants under the argument that their products are ‘safe’ and therefore can beneficial in creating products for the poor. This indicates that despite awareness of the issues of nanotechnologies, actors still choose to dismiss the issues in practice due to their unanimous optimistic view that nanotechnologies can benefit society. A similar attitude was seen in a study on perspectives of scientists in India (Patra et al. 2010). In this study the potential negative effects of nanomaterials were largely ignored by scientists in India because they did not believe that R&D in nanotechnologies was unethical, despite concerns of safety.

However, whilst certain bio-based nanomaterials may be safe, some scientists that participated in this study pointed out that slight changes in the structure and size of the material can be harmful to human health and environment. Similar debates have been rampant in various literature and past toxicity studies conducted by scientist. Literature has also shown that regulators are confused as to what constitutes a natural ingredient. Moreover, many of the substances in the past that were previously considered to be harmless (e.g. asbestos), “false negatives”65 (European Environmental Agency 2001), were later found to be harmful to human health (RCEP 2008).

Furthermore, by referring to the GRAS list, food technology developers and users in the U.S. are allowed to independently determine whether a substance in food is safe without having to notify FDA. Pre-market approval requirements also does not extend to substances that are GRAS (Taylor 2006), and engineered nanomaterials are entering the food supply chain as GRAS substances without the actual knowledge of the FDA and thus able to bypass the regulatory system (Kirby 2011; Buzby 2010; Beaudrie 2010). Thus, GRAS has incomplete statutory and regulatory authority to control nanoscale food additives, and certain nanomaterials may escape regulatory reviews on the basis that these substances are already on the GRAS status (Duvall 2012). For example, macroscale silicon dioxide has a GRAS status where migration from packaging into food is accepted, but nanoscale silicon dioxide may not have the same standard of safety and thus regulating it under GRAS is debatable, especially as

65 Activities that were considered at one time as being harmless “at prevailing levels of exposure and ‘control’” by various stakeholders, including governments, until evidence emerged of their harmful effects.
there is only a voluntary GRAS notification required. This can also be an issue in Canada, where it was pointed out by a policy-maker that a pre-notification for novel food packaging products is voluntary, and responsibility lies with the manufacturer. This voluntary submission notice suggests that manufacturers are able to easily manufacture nano-based packaging and penetrate markets without any pre-market assessments.

7.3.2 Who is responsible?

One of the main aspects of the research question was to understand, who, in the nanotech F&FP industry, do the actors consider is ‘responsible’ for the governance of nanotechnologies. The research found a number of areas of consensus on participants’ views on responsibility.

A majority of participants in both, Canada and India pointed to a “shared responsibility” among actors (see Chapter 5, section 5.4.2.1 and Chapter 6, 6.4.2.). A heterogeneous group of actors within a food chain, right from the researchers, farmers, producers, manufacturers, retailers to the government, industry, NGOs, industry associations and consumers, were considered to have equal ‘responsibility’ in ensuring the safe and ‘responsible’ development and commercialisation of nanotechnologies. Each individual actor within the food chain was perceived to have some ‘responsibility’ and no single actor group was alone responsible. This finding is consistent with literature where it has been pointed out that it is not the responsibility of an individual but a collective responsibility of stakeholders (von Schomberg 2013; McCarthy and Kelty 2010) when it comes to the governance of nanotechnologies.

Thus, according to participants, manufacturers and producers are ‘responsible’ because they know what is in the product; the government is responsible because they have the authority to set regulations, approve products and have the onus/duty of ensuring public heath and safety; the retailers are ‘responsible’ to ensure that what they put on their shelves are safe. There is also the ‘responsibility’ of the scientists to ensure that research carried out by them is carefully tested to ensure it is safe to use. According to Forloni (2012), the role of the scientific community is essential to the ‘responsible’ development of nanotechnologies as they are a link between safety procedures of nanotechnology and commercialization, which in turn could lead to the development of regulations (p.6). Interestingly, scientists in India were in consensus that the first and main ‘responsibility’ for ensuring the safety of nanotechnology rested on them as any products that eventually enter markets are first developed at scientist labs. The second
responsibility was on the government that approved all products. However, there was a third group of participants that pointed out that the users and public were equally responsible as they had to ensure that they used the products responsibly. Therefore, whilst the notion of shared responsibility was prevalent across Canada and India, there appeared to be a larger ‘weightage’ given to certain actors that were considered to be more or less responsible in the governance of nanofood and packaging.

7.3.3 Involvement of intermediaries in RI of nanotechnology

7.3.3.1 Role of CSOs/NGOs

There is a growing recognition of the important position of CSOs/NGOs in discourses on emerging technologies.

It is clear from the empirical data that NGOs in both, Canada and India, are involved in nanotechnology issues at an early stage of development.

While, sections 5.4.2.7. and 6.2.3.2 provide a strong consensus among actors on the important role of NGOs in the ‘responsible’ governance of nanotechnologies in Canada and India, this study found that the roles of NGOs differed in Canada and India

While in Canada, the role of NGOs is seen to foster public debate around issues of EHS of nanotechnologies, in India, NGOs are being uniquely used to support the introduction of nanotechnologies in rural areas in India. The presented findings (see Chapter 6, section 6.2.3.2), show that Indian NGOs are actively involved in taking nano-products from the laboratory to the field. Through constructive dialogues with farmers at the grassroot level, NGOs (and KVKs/extension agencies) are used to educate farmers and people in villages/rural areas about the benefits and risks of nanotechnologies, while also helping them get economic benefits out of the technology. This unique model for introducing nanotechnologies suggest not only the important role of NGOs in the promotion of nanotechnologies and its acceptability, but also farmers’ undue trust in NGOs. It may also be argued that the adoption of this approach is a focused attempt to pre-empt public resistance, similar to that which occurred with GMO. Thus, the use of NGOs to promote technology in rural India is a growing trend. While a similar use of NGOs was seen in the energy sector, when First Energy Oorja, a collaboration between IISc
and British Petroleum (BP), promoted cooking stoves to replace traditional man-made stoves through NGOs (Vijaya Lakshmi K. et al. 2011), this is unique to the case of nanotechnologies.

It is also evident from these findings that some NGOs in India appear to be very adopting of nanotechnologies. NGOs are focused to reducing poverty (Wallace and Lewis 2000) and this study provided evidences of NGOs seeking new technologies, such as nanotechnologies, to help the poorer sections of society. Moreover, the public too have higher levels of trust in NGOs and their (social) scientists; hence the use of NGOs to propagate nanotechnology to farmers mitigates the possibility of non-acceptability of a new technology.

While researchers and organisations promoting nano-products within these villages/rural regions anticipated much opposition from farmers and public, this was not the case in India. This study found that while there was slight apprehension among farmers about the use of a new technology, the use of intermediaries, where “locals help locals”, aided in appeasing any resistance and overcoming potential public backlash. Furthermore, with the public disillusioned with government and corporate practices, they are continuously putting more and more trust in these intermediaries that demand and focus on ethical practices (Nugroho, 2009). As the acceptance of new technologies rests mainly on the public and with the public giving more and more power and attention to these representative organisations to represent them, both the public and private sectors are also slowly including these NGOs in their activities involving new technologies. Thus in India, NGOs are used to train farmers in using nanotechnologies in their fields, while helping them overcome some of the socio-technical constraints that exist in India due to past GMO controversies. Companies too are using NGOs to help introduce new products, like nanosilver water filters in villages. Both Hindustan Unilever and Eureka Forbes, leading MNCs, have also used NGOs to promote their nano water filters in rural areas.

It is anticipated that the success of these programmes and early intervention of NGOs will in future help to promote the use of new technologies to a larger group of farmers and poor people across various regions in India. Prior studies have emphasized the importance of early inclusion of various actors, social and technical scientists, civic organisations, etc. in addressing long-

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66 In 2008, many farmers began committing suicide due to loss of crops, which was blamed on the use of GM seeds (Malone 2008)
term issues of ethical, moral, legal, economic and environmental societal implications (Roco and Bainbridge 2003), rather than making adjustments as developments advance.

Furthermore, NGOs have the ability to influence actions from organisations and governments and should not be underestimated (de Bakker et al. 2014). In Canada, as activists, NGOs play a strong and complementary role to regulatory governance, where some groups have even called for a moratorium on nanotechnology (ETC Group 2003b). The majority of CSOs/NGOs that were interviewed in Canada were predominantly concerned about the risks of nanotechnologies and the governance gaps in the absence of specific nano-regulations. They were often found to be present in policy debates, voicing their concerns on the risks of the technology and continuously calling on the government to address issues of EHS and regulation of nanotechnologies. The inclusion of CSOs/NGOs to address the potential risks and the ‘responsible’ development of nanotechnologies has also been emphasized in an early study on nanotechnology risk governance, where CSOs/NGOs were found to engage with various stakeholders to deliberate on topics such as public engagement, standard and policy development and societal implications of nanotechnologies (Renn and Roco 2006). Such actions have been noted by Braithwaite and Drahos (2000) in the past, who have regarded NGOs as playing a key regulatory role in regulatory developments.

A common notion favoured by most of the participants in Canada, including government officials, was the inclusion and participation of CSOs/NGOs in the governance of nanotechnologies. In particular, participants believed that NGOs were the ‘mouthpiece’ of the public and provided essential opinions and views needed for governing new technologies. In the presented findings (see Chapter 5, section 5.4.2.7) actors have also acknowledged that the NGOS are essential watchdogs (Kelemen 2000; Roht-Arriaza 1995) of the activities of companies who have the capabilities to force government to develop regulations for nanotechnologies and they should be heard as they have no personal agenda besides protecting public interests. The literature has shown that in order to widen involvement, discussions of regulatory governance require the active participation of the CSOs in regulatory dialogues and national governments are continuously relying on the knowledge of NGOs to assist and advise them on regulatory aspects. Moreover, studies have pointed that the debate on GMO was further aggravated by the government excluding such groups in policy debates (Toke and Marsh 2003; Sassatelli and Scott 2001). The inclusion of NGOs in nanotechnology policy
debates thus suggests that the GoI is interested in ensuring CSO’s/NGO’s perspectives are included in the governance of nanotechnologies, including those gathered from NGO publications and websites. Thus, we find NGOs contribute to the democratisation of regulation of nanotechnologies in Canada, where regulatory dialogues often include participation from CSOs/NGOs and consumer representative groups for their inputs on regulatory governance of nanotechnologies.

However, the findings also show that despite being included in regulatory dialogues the inputs from these CSOs/NGOs in Canada are often ignored over industry consultations and in some cases NGOs are often excluded from important policy debates that involve discussions with organisations. It is evident from these findings that regulators are often biased towards particular interest groups (Buchanan 1972), and thus there is inefficient bargaining between the interest groups (Laffont 1999). Several studies have also shown that regulators tend to favour producer interest groups (Stigler 1971). In a preliminary study published by the European Environment Bureau (EEB), NGOs have argued that the European Commission’s recent review on transparency measures for nanomaterials in the market are biased and leaned towards industry’s economic interests and have thus failed to address environment and health safety concerns, and therefore disregarded public right to information (EEB et al. 2015).

However, in defence, participants from industry associations in Canada pointed out that NGOs are against new technologies and therefore should not be given much attention. This perception of associations provides further evidence of NGOs’ exclusion in discussions of new technologies in important policy debates, where large firms may be present to discuss their innovations in nanotechnologies. The relationship with organisations and NGOs is often antagonistic, as NGOs constantly question organisations’ morals on their activities. This is evident in the debates around GMO, where NGOs have come together in highly public demonstrations against companies like Monsanto that have incorporated GM in their research activities. Campaigns by NGOs were also directed against companies such as McDonald’s when they were using nanotechnologies in their food packaging (Miller and Senjen 2008). Such incidences make companies cautious in disclosing their activities in the presence of NGOs that have the power to damage their reputation and stifle ‘beneficial’ innovation.
Furthermore, NGOs may be local, national or international and while some may operate with only few members in their group (e.g. Friends of the Earth, The ETC Group), others may have a larger representation of members (e.g. UN, Amnesty International). However, despite the small number of representations from NGOs in Canada in these policy debates, the findings show that NGOs do have a powerful voice, enough grit and persuasion muscle to coax responsible behaviour from industry, as well as influence government to involve them in policy debates where they can voice their opinions.

CSOs/NGOs have a way of gaining attention and are often seen to engage in a variety of activities like protests, media conferences, demonstrations, petitions and publicity stunts to force behaviour modification. In December 2013, a group of consumer advocates and environmental activists, such as the International Centre for Technology Assessment, Friends of the Earth, the Centre for Environment Health and Food and Water Watch, sued the U.S. FDA for failing to respond to a petition filed by them in 2006 calling for regulation of nano-enabled products (FoE 2011). This forced the FDA to take greater steps in safety assessments of nanomaterials in cosmetic and food products by setting out guidelines for industry in 2014 (FDA 2014). More recently in December 2014, the International Center for Technology Assessment (CTA), along with other NGOs, filed a case against EPA over the U.S. agency’s failure to regulate nano-silver in pesticides (ICTA 2014). Similarly, in Canada, a consumer representative group has been campaigning for several years to bring the issues and regulations of nanotechnology forward within the Canadian parliament through MPs, and as part of the ISO technical committee has also proposed labelling of nano-products. Another Canadian activist is pushing to establish a convention at the UN level to assess and provide global transparency and oversight for the introduction of nanotechnologies. Such activities are expected to help advance the promotion of the ‘responsible’ governance of nanotechnologies on a legalistic level in Canada and beyond.

However, despite endeavours to bring forth issues of nanotechnologies, participants from CSOs/NGOs in Canada have pointed to challenges in attending policy debates organised by government agencies due to lack of funding. While NGOs do not need large budgets, they do have the power to “mobilize mass publics around their concern” (Braithwaite and Drahos 2000, p.500). According to Bakker et al. (2014), the media becomes their tool for publicising issues and concerns more openly and widely, and use them to their advantage. However, NGOs have
also come under criticisms for irresponsible behaviour and often accused of misrepresenting facts, changing evidence, exaggerating risks and amplifying issues (Pidgeon et al. 2011). Such exaggeration can create a non-acceptability of nanotechnologies and subsequent moratorium of this emerging technology.

Thus, NGOs vary enormously in their focus and operations and cannot be considered as a homogenous group, although as seen here they are all leaned towards some form of social justice (Elbers 2004). While NGOs in Canada consider nanotechnologies as a risk to society, in India NGOs see the technology as a benefit that promotes the betterment of life to the poorer section of society. While in Canada, NGOs are branded as “extremists”, in India, they are perceived as advocates of new technology, where scientists and companies in India are using NGOs to help take nanotechnology from laboratory to field. Thus, NGOs in both Canada and India are seen to have asymmetrical but very active roles in their respective regions when it comes to the ‘responsible’ governance of nanotechnologies.

### 7.3.3.2 Building trust through celebrity endorsement of nano-products

Another unique and important finding in this study revealed that nano-based products were also being openly advertised by celebrities in India. This finding reveals that celebrities play a crucial role in perceptions of nanotechnologies among the public.

Participants in this study pointed out that various nano-products that were being openly promoted through advertisements and TV commercials using Indian celebrities like well-known actor, Amitabh Bachchan (see Appendix 3). This has helped build trust among the general public, where the endorsement by a celebrated and trusted celebrity has created a perception that the product is safe. Such positive views of nano-products in the media and celebrity endorsements have resulted in attention being diverted away from the potential risks of the technology.

Past studies have shown that while technical information do not have any impact on acceptability of novel technologies, endorsement and use of novel technologies by opinion leaders, prestigious people and federal agencies or reputable international organisations with

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67 TV Commercial for Tata Swach water filter can be viewed here: [http://www.tataswach.com/media/tvc.html](http://www.tataswach.com/media/tvc.html)
expertise in the area of technology, play a key role in shaping people’s perception of the technology as their opinion is trusted (Bord and O’Connor 1990). We have seen the results of the comments made by well-known figures like Prince Charles on safety of nanotechnologies and how it was framed in the media and made newsworthy of the issue (Anderson et al. 2005). Another example can be illustrated through the participation of various celebrities like Danny DeVito, Dave Matthews, Emily Deschanel in the GMO Right To Know campaigns in the U.S. for labelling of GM products (Hirshberg 2012). Both these cases point to the importance of celebrity opinions on emerging technologies and subsequent public view. We also know from these examples that involvement of celebrities significantly affect media coverage (Corbett and Mori 1999), increasing newsworthiness of the issues of new technology, where celebrity opinion is given much attention and trust.

In Canada, such overt expressions on the benefits of nanotechnologies are limited or confined to conferences. Companies refrain from advertising products incorporating nanotechnologies. However, during my visit to Canada, I discovered a very interesting and unique case of a yogurt that carried the word ‘nano’ on its packaging (see Appendix 9). Whether, the use of the term ‘nano’ on the yogurt product is used as a synonym to indicate ‘small’ or to identify the product as being distinctively different in technology, is uncertain. Studies have shown that ‘nano’ is often used by companies in products even if it does not contain any nanomaterials (Gruère 2011; Beumer and Bhattacharya 2013). However, the absence of advertisements for nano-based products in Canada can only suggest that companies are fearful of disclosing their use in F&FP. This also demonstrates the strong powers of the NGOs and the media in raising issues of new technologies.

Canadian firms also refrain from using the term ‘nano’ on their product for fear of negative repercussions (see Chapter 5, section 5.3.5). This avoidance of the use of the term ‘nano’ may be further related to companies’ wanting to distance themselves from any association with nanotechnologies, which has seen continuous negative reactions, and therefore avoid any reputational damage. This fear of the use of the term ‘nano’ can also be seen in the name change that occurred when the Nanotek Consortium, established by Kraft in 2000 for R&D of

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68 In 2004, Prince Charles raised questions about the potential risks of nanotechnology and called for a safety review of nanomaterials, which created much media frenzy (The Guardian 2003)
nanotechnologies, was renamed by Philip Morris (after it took over the consortium), to Interdisciplinary Network of Emerging Science and Technologies (INESST) to avoid any connection to nanotechnologies (UK House of Lords 2010b, p.17).

7.3.3.3 Trust in industry

As pointed out in the findings and literature, companies in India are developing and commercialising nano-filters. Some of the larger well-known companies in India were instrumental in developing the product to help people in villages get access to clean drinking water. Despite the use of a new technology, villagers welcomed these products solely based on their trust in companies that are well-known and highly revered by them. This acceptance of the product can be related to two aspects – trust in the company to provide safe products, and companies’ reputation for quality products. Often these companies would have had previous CSR-related interactions with the villagers or have been known for their high quality products. Thus, villagers are willing to accept the products introduced by them because of their previous credible records and high reputation for quality consumer products. A market study during a personal visit to India also found that some of the larger well-known firms had explicitly labelled their nano-products (see Appendix 3 & 5). However, there are no formal policies for disclosure of information for nanomaterials. This means that water filters with nanosilver are being marketed by large companies without adequate information being provided on the shelf life or safety issues on the use of nanomaterials, nor are tests being carried out on a regular basis to ascertain efficiency of these filters (Vijaya Lakshmi K. et al. 2011).

In contrast, findings from interviews with Canadian participants showed that Canadian F&FP firms were reluctant to speak about their involvement in the R&D of nanotechnologies. Many actors related this behaviour of the industry to a fear of public backlash and subsequent reputational damage. Thus, the controversial debates on biotechnology and GMO and subsequent public criticism of companies using these technologies, has forced Canadian companies to keep a lid on any activities that incorporate nanotechnologies. Furthermore, there have been continuing public backlash and calls for labelling of GM foods, as recent as January 2015 (Food Safety News 2015). From the findings it is evident that the Canadian agriculture

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69 A sister subsidiary of Altria
industry suffered major losses when the EU banned import of all GM foods (see Chapter 5, section 5.5.1). With such ‘lessons learnt’ from the GMO debacle, this can be a possible explanation why industry continue to be reluctant to discuss the use of nanomaterials in food innovations and new products. However, as found in this study, such secretive behavior has resulted in firms being viewed as companies that are only interested in their bottomline, and thus could not be trusted for the governance of nanotechnologies.

7.4 Creating markets for nanotechnologies

In the previous two sections, I provided an understanding of the commonalities and differences in national regulation and governance regimes for nanotechnologies in F&FP sectors, while also highlighting the difference in interpretation of what it means to be ‘responsible’ in Canada and India. In this section, I bring these differences and varieties in interpretation to investigate how these notions of ‘responsibility’ and regulation are constructing markets for nanotechnology in Canada and India (specifically). Therefore, this section seeks to answer my main research question: “How do notions of ‘responsibility’ and regulation affect different geographies and markets for nanotechnology?”

7.4.1 Focusing on research collaborations

This study found that both Canada and India are actively collaborating on various F&FP, including agricultural research projects incorporating nanotechnologies. While these collaborations provide both countries the opportunity of a huge market, both domestic and international, it helps India publicise its competencies and skilled scientific workforce in nanotechnologies on a global platform. India is heavily dependent on such collaborations to make its presence in the international global market. Moreover, collaborations bring in much-needed funding for innovative projects from OECD partners to developing countries. Another benefit of collaborations is the responsibility other countries may assume to help countries with social problems. This was evident from the Mango Project, which was funded by Canada’s funding agency, IDRC, to develop a nano-film for packaging for the benefit of poor farmers in India (see Chapter 5, section 5.5.2.1). These findings further support the early ideas put forward by Salamanca-Buentello et al. (2005) that the funding for the development of applications of nanotechnologies that could help in achieving some of the UN MDGs, would come from national and international foundations and collaborative projects. It can be expected that such
projects not only have the potential to benefit scientists and mango farmers in India but also provide Canada the opportunity to use the technology. Canada has the largest land area in the world for agriculture and these collaborations that focus on agricultural goods can be redirected or reapplied to fruits and vegetables in both, Canada and India. Thus, such collaborations bring mutual benefits for trade and commercialisation for the two regions.

On the other hand, there have been claims in the past that nanotechnologies are an instrument used by developed nations to maintain their dominance over developing countries (ETC Group 2003a). It has also been pointed out that developing countries are continuously used as a ‘guinea pig’ or ‘dumping ground’ by industrialised nations to test new technologies and sell products that otherwise would not be allowed in their own countries (Miller and Scrinis 2010). The testing of the hexanal solution and biosafety tests on animals being carried out in India point to the fact that these tests would not have been permitted in developed countries and thus were being sent to India due to its low regulation.

7.4.2 Growth of nanfood and packaging products in markets

The empirical study has shown that there is growing R&D of nanotechnologies in F&FP in both, India and Canada, and various patents have already been applied for. Findings point to a growing trend in nanofood packaging in the areas of active packaging and sensors in Canada and India. There is great potential for nanofood packaging products to enter Canadian markets as manufacturers in the packaging sector already have market-ready products for retailers and producers, as found in this study. Previous studies have identified food packaging as the most promising area in R&D of nanotechnologies (Robinson and Morrison 2010).

According to participants, the trend in recycling is also an increasingly important issue in Canada. The recyclability of packaging in F&FP is an important consideration within the Canadian industry where nanotechnologies are expected to provide benefits in this area. Active packaging and functional foods are also likely to be an area that will see some development considering Canadians are inclined towards health and nutrition.

India and Canada are tied as the world’s leading exporters in food commodities; The R&D of nanotechnologies in food and food packaging, including agriculture (F&FPA) is thus strategically important for this sector for both these countries. Moreover, the food industry in
Canada has faced many crises in the recent past and are looking for solutions that can help curtail such mishaps. Nanotechnologies for the detection of pathogens in F&FP products is seen as an important trend that is likely to be adopted by organisations in the food industry. Thus, companies are interested in looking at how they evolve and how they can be utilized in the business. However, this study found that companies are wary of using nanomaterials without regulations. Thus, it is expected that incorporation of nanotechnologies in food companies will only follow after regulations are more specifically defined. This suggests that the capacity of the State to provide regulations will be a strong determinant in the construction of markets of nanotechnologies in F&FP.

In India, on the other hand, many food products are already in the market. Thus, contrary to the belief that large corporate bodies have not harnessed nanotechnologies (TERI 2007), this study shows that large organisations are involved in the uptake of nanotechnologies. From the empirical study, there are also indications of many products being developed not only at government-led institutions, but by smaller private firms where entrepreneurs are carrying out their own R&D, manufacturing and selling products incorporating nanotechnologies. For example, nanotechnology is being used in nano filters for purification of water; in formulations for higher plant nutrient uptake in agriculture and fisheries; nano-packaging in snacks and ready-to-eat foods; and in restaurants. Interestingly, this study found that one of the products, a silver-based nano-membrane for water filters, was developed at the government’s CSIR laboratory, which was later transferred to an organisation and commercialised. This open endorsement by a government organisation in promoting nanotechnologies and the availability of a number of nano-based products in the market has provided companies the motive for developing nano-based products, where it is expected that more products will enter markets over the years. Many of these products developed in India are being marketed to other regions of the world. For example, nano-filters have been exported to Africa and the U.S., mangoes grown through the use of nano-based agricultural formulations are being exported to the UK; solutions for aquaculture are being sold to the U.S.; and nano-based spices are being exported to Dubai. Thus, we find that a global market for F&FP, including agriculture, has already been created in India. However, Lee and Jose (2008) point out that the market potentials of nanotechnologies may drive companies to place products in the market without adequate ethical considerations and analysis (p.119).
While, various products in agriculture and food are being exported to countries around the world and found in the market, most government officials that were interviewed, appeared to be unaware (and almost indifferent) of these nano F&FP products in the market, though these are openly sold, advertised and covered in the media. Such lack of knowledge by government officials in terms of what products are there in the market, is not new. Previous studies have pointed out similar lack of knowledge of what nanomaterials are in the market. For example, in a study by EEB, this discrepancy is shown in the French register, which has listed up to 422 substances of nanomaterials in the French market, whereas the Commission Staff’s Working Paper highlighted just 20 nanomaterial substances in the EU (EEB et al. 2015).

Recently India did initiate a voluntary registry inviting innovators to disclose their activities in nanotechnologies. However, while these may provide a database of nano-activities in F&FP, these are perhaps largely meant to collect data on research activities for commercialisation and trade purposes, rather than for risk studies.

In Canada, there is awareness among various government agencies about nano-products in the market but an inventory of available products is unavailable as disclosure of use of nanomaterials is voluntary in Canada. Many countries, such as Australia, have introduced similar voluntary reporting schemes (Falkner and Jaspers 2012).

7.4.3 R&D by firms

This study found that due to the absence of stringent policies, many large and small firms and entrepreneurs in India are already taking advantage of the potentials of nanotechnologies in F&FP and penetrating the local and international markets with nano-based products and solutions. According to participants, there are various institutional bodies that overlook regulations in different sectors. For example, for medical, there is the Medical Council of India, for drugs it’s the Drug Controller of India, for pharmacy there is the Pharmacy Control of India, for fertilizers there is the Fertilizer Control of India, however, as participants pointed out a ‘Nanotechnology Control of India’ to regulate the sector is absent. Thus, as nanotechnologies does not fall under any of the current categories for regulation, smaller firms are freely able to research, develop and commercialize nano-products, including those in F&FP and agri-food products. The consequences are that products are continuously entering markets at a faster pace than any form of standards and regulation that could keep it in check (Bürgi and Pradeep 2006).
It has been emphasised by many international bodies that there is a need to build institutions and improve regulations in developing countries in order to help better “supervise the private sectors” (World Bank 2001; Asian Development Bank 2000)

However, this study found that despite the active R&D of nanotechnologies in India, smaller firms and entrepreneurs face many challenges when marketing their products in India and were calling on the government to make regulatory decisions on nanotechnologies to enable them to sell their products easily. As their products are not categorized as agricultural (explained above), smaller companies faced various issues. These included increased taxes on non-agricultural goods and problems at customs during the import and export of nanomaterials and nano-products. Moreover, farmers in rural regions were seen to have less faith in smaller companies (as compared to larger reputable firms) involved in promoting products that did not fall under specific regulation and were thus wary of using them. Under such negativity, these companies were thus seen to be using various promotional activities including communication vehicles, such as radio and newspapers, face-to-face interactions and NGOs to help educate farmers on nanotechnologies and the benefit of their products. In contrast, larger, powerful firms were better able to market their products (e.g. nano water filters) in rural and urban areas solely based on their high reputation and trust in the brand. From these findings, we can suggest that the Indian Government’s open culture on innovations of nanotechnologies and funding towards nano F&FP projects, has provided researchers and entrepreneurs the confidence to carry out R&D using nanomaterials, invest resources in the technology and market products of F&FPN.

Conversely, in Canada, F&FP firms were fearful of overtly expressing any interest in nanotechnologies or using nanotechnologies in their products. First, due to regulatory uncertainty Canadian firms are cautious about using nanotechnologies in the food sector. With concerns about the risks of nanotechnology looming in public debates the food industry is fearful of the direction that nanotechnologies will take and unwilling to invest in research or openly acknowledge use of nanotechnologies until there is government-backed regulations and public acceptance. Thus, they are playing their own ‘waiting game’. These findings are consistent with similar studies in the past (Tachikawa 2012; Gruère 2012). While this may suggest that food companies in Canada take risks seriously, many companies have acknowledged potential benefits that nanotechnologies can offer in F&FP products, and are
preparing to gain from these potential benefits by partnering with research institutes in Canada for R&D of nanotechnologies. Thus, despite companies’ unease in disclosing their activities, various research projects were found to be underway within firms and in partnership with universities. This suggests that while companies do not appear to have an articulated strategy in nanotechnologies, it is in their radar to explore the potentials of this new technology for future competitive reasons. Such approaches can also suggest that public-private partnerships provide companies a ‘cover’ or protection and low-risk solution for organisations, where it is partly funded by the government and thus ‘endorsed’ by them. Furthermore, such initiatives can also be seen to provide government with access to information on the risks of nanotechnologies and the knowledge on the ongoing activities by organizations.

Second, companies in Canada are unwilling to take the lead, even if there is general acceptance that the technology is highly promising because of the potential risks linked to the technology. A major deterrence for food companies in Canada is the absence of specific regulation. Where there are known risks, regulation can be implemented; but in the case of scientific uncertainty, regulation can be challenging (Berube 2012). This leaves nano-innovators with further uncertainties as to when the regulation of nanotechnologies will come in place, or what form of frameworks will be put in place (Silva and Robinson 2012). While this puts pressure on the GoC to develop regulations because innovators would be wary of (openly) applying nanomaterials in their products unless there is clarity on the regulatory landscape, regulators, however, are in a dilemma of regulating too early, which could stifle innovation, or regulating too late (Randles 2008), which could result in unsafe use and distribution of nanomaterials, and therefore failing to take preventive measures to safeguard society (Silva and Robinson 2012). A study by Nielsen observed that a majority of consumers in Canada do not trust the government and pointed out the need for a stricter regulatory stance that should be taken by the government to regulate nanotechnologies and address all social and ethical issues (Nielsen, 2008). Moreover, there is limited trust on corporations and their business leaders when it comes to nanotechnologies minimising risks pertaining to nanotechnologies (Macoubrie 2005), which make it difficult for companies to justify their actions in case a catastrophe occurs. Thus, while it is being emphasized to companies that they need to be transparent on their use of nanotechnology in food (Duncan 2011b), these challenges of acceptability make it difficult for companies to openly disclose their use in a country with low acceptability rate. Research in the past has found that while consumers in developed countries are more accepting of new
technologies (Satterfield et al. 2009, p.757), there is less acceptability of innovations in food and food-related products (Eurobarometer 2010; Marette et al. 2009; Siegrist et al. 2007; Lyndhurst 2009) which can further explain why companies are dissuaded from disclosing its use and/or using it. However, while companies may be justified that engaging too early makes them vulnerable to public criticism and backlash and subsequent loss of commercial advantage, engaging too late with the public could lead to implications of “social legitimacy” (Groves et al. 2011, 545).

Third, companies are also put off by Canada’s stringent laws that take years to approve new substances in F&FP. Hence, they are reluctant to invest in a new technology that has no immediate returns and therefore choose to take their innovations outside of Canada, such as the U.S.A. where there is less regulatory restriction.

Fourth, companies are in constant pressure to improve food safety and increase profit (Dingman 2008). As pointed out, in Canada, producers are reluctant to invest in technologies without a demand from customers/users and thus have a very passive approach towards nanotechnologies. Thus, unless there is wider acceptance of nanotechnologies in F&FP, companies, including investors, will be unlikely to invest substantial amounts of money in nano-based products that may not bring immediate profits (Marette et al. 2009). Studies have shown that the food industry’s adoption of nanotechnology has been slow (UK House of Lords 2010, p.18) because of low margins (Cientifica 2007). Large food firms that were investing in nanotech F&FP R&D in the past (e.g. Kraft, Heinz, McDonald’s, Unilever, Nestle, etc.) have now also refrained from investing in nanotechnology because of the regulatory uncertainty and possible public backlash (Schneider 2010). Moreover, some food companies that were overt about their R&D in nanotechnologies (IFST 2006) were now unwilling to disclose any information relating to their activities (UK House of Lords 2010, p.17). Hence, these various challenges refrain companies from disclosing their use of nanomaterials in their F&FP products.

Scaling up the technology – transferring from the lab to manufacturing units - was also seen as an issue by actors. The uncertainty of toxicity of nanomaterials developed in bulk form as against that developed in small scale in the confines of a protected environment in the laboratory, was pointed out by a scientist in Canada. Some participants in the Canadian and
Indian industry elaborated on the “valley of death” due to lack of ‘takers’, market uncertainty, technical risk and inadequate evidence of return on investment. In India, firms with access to a bulk market, were also fearful of developing nano-based packaging material on a large scale lest there were complications and therefore were using nanomaterials on a smaller scale. These same challenges of technology transfer and commercialisation has been emphasised in the past. The reluctance of the industry in India to manufacture nanomaterials on a large scale has been discussed in earlier literature (Sharon 2013). Shortage of funds in creating product prototypes and scaling up, the lack of nano-marketing facilities to promote the technology, absence of in-house capabilities to prepare techno-commercial documentation for technology transfer, bureaucracy in institutes, lack of early involvement of industry which also makes them unaware of available technologies/opportunities, risk-averse industry with no access to risk finance or incentives, and lack of regulation/policies has also been highlighted in earlier studies (Purushotham 2012). These challenges have further mitigated the process of technology transfer from the laboratory to industry.

The regulatory and market uncertainty, potential risks from the technology, economic costs for scale up and development and consumer non-acceptability, which has made companies reluctant to invest in nanotechnologies or be the first to bring products to market, has been highlighted in literature as “waiting games” by producers (Parandian et al. 2012; OECD 2013; Robinson et al. 2012).

Conversely, this study found that the industry in India were more open about their activities in nanotechnologies. Various companies that were approached about their nanotech activities were willing participants in this study and showed a keen interest in discussing their research in nanotechnologies. In contrast, Canadian companies were unwilling to discuss or disclose their activities and various companies that were approached declined the request for interview stressing that they did not participate in any activities, even though interviews with other actor groups did reveal their activities in nanotechnologies. Despite, their interest in the technology, this lack of response appears to be distinctive of companies, especially those using nanomaterials (Behar et al. 2013). While the fear of public backlash and reputational damage was constantly elaborated by actors in this study as legitimised reasons for the secretive

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70 A gap between a laboratory discovery and the advancement of the discovery into a commercial product
behaviour of the industry, lying or withholding information, and not giving people the opportunity to make informed choices, goes against the fundamental principles of ethics (Kant’s philosophy). According to the theory of ethics of rights, which focuses on the action of the firm (rather than consequence of the technology), by withholding information, firms would not be moral.

On the other hand, the ‘openness’ of Indian researchers and firms can be related to their enthusiasm to share their research results. Participants from firms with products and processes of nanotechnologies were found to be much more overt and ‘transparent’ about their activities in nanotechnologies. There was a willingness by participants to discuss their activities openly in interviews. There were also cases of these organisations openly advertising their products and services in markets as discussed in 7.3.3.2. From this, it is clear that there is an effort in directing the attention of consumers to nano-based products in the market. Once the consumers are aware of the product, they would want to buy them, and subsequently demand for them, thus creating a new market for producers (Kirzner 2000). However, it was indicated by participants that nanotechnology is a buzzword in India and many organisations (mis)use the term to promote products (see Chapter 6, section 6.2.3.1) even if products have no affiliation to the technology (e.g. Nano Tata car). The use of ‘nano’ as a promotional term, “technological fashion” or a corporate and marketing buzzword has been reiterated many a times in past literature (Gruère 2011; Drexler 1987; Selin 2007; Allhoff and Lin 2009). The fact that the term ‘nano’ is being openly used in India on various products reinforces the idea that consumers in India are open to new technologies (and perhaps accepting) and companies in India are keen to call attention on their products through the use of such new scientific terminologies that appear attractive to consumers. This perception and framing of technology within the region and open innovation culture are therefore likely to generate a market for nano F&FP products in India.

7.5 Conclusions

7.5.1 Summary of this chapter

This chapter provided an overall assessment of the perceptions of RI in nanotechnologies in the two cases of my study, Canada and India. It offered a comparative analysis of the perceptions of actors on their notions of ‘responsibility’, as well as policy contexts by which
nanotechnologies in F&FP is regulated in Canada and India. Focusing on the varieties of notions of ‘responsibility’, I discussed the main findings, using the summaries from Chapters 5 and 6, through a comparative case study analysis between Canada and India. The outcomes of the findings were discussed through the five scenarios in Canada and India and contrasted against existing theory and literature. Table 8 briefly outlines the comparative governance structures as discussed in this chapter. The discussions introduced seven varieties in ‘responsibility’ in two diverse regulatory settings, while simultaneously focusing on the differences and commonalities. These included:

(i) multi-stakeholder deliberative dialogues involving scientific, institutional, and industrial communities and the public
(ii) support by government in domestic R&D to help steer industry into commercialisation and stimulate economic growth and development
(iii) introduction of standards and policies through collaborative initiatives with international regulatory committees to establish new markets for nanotechnologies;
(iv) putting trust on scientific expertise, NGOs and responsible businesses for the ‘responsible’ development of nanotechnologies
(v) focus on socio-economic needs of the nation
(vi) globalisation and internationalisation of collaborative EHS projects between developed and developing nations; and
(vii) consumer choice where attitudes towards nanotechnologies are framed by celebrity advertising and media.

The chapter contributed significantly to the understanding of the culture and progress towards RI within these geographies (keeping in mind that these nations play a key role in global markets), and provides useful knowledge into the growing engagements of nanotechnologies in the F&FP sectors in an emerging, non-OECD market like India, and developed/established, OECD economy like Canada.

7.5.2 Connecting to Chapter 8

In the final chapter of my thesis, Chapter 8, I will present the conclusions and implications of this study, outline the contributions of this study to knowledge, propose areas for future research and provide some recommendations.
In summarising my final comments, I argue that the Western understanding of a culture of low regulation in emerging economies like India, may not adequately capture various understandings of the notions and practices of ‘responsibility’ and RI when it comes to governance of new technologies like nanotechnologies. It is therefore important to take into perspective the varied notions of ‘responsibility’ as captured in this study, when establishing international laws and policies for governance of nanotechnologies. Furthermore, I argue that ‘responsibility’ in India is greatly influenced by dominant nations in the developed world where certain criteria for the ‘responsible’ R&D of nanotechnology is enforced through bilateral research projects. This demonstrates the return of the State. Thus, responsibility is exercised across transnational networks through symmetric notions of responsibilities in asymmetric landscapes.
CHAPTER 8

CONCLUSIONS: GOVERNANCE OF NANOTECHNOLOGIES THROUGH VARIED NOTIONS OF RESPONSIBILITY

8.1 Introduction

8.1.1 Connecting from previous chapters

This study combines my interests in innovation, nanotechnology and ethics/responsibility. Initially, I proposed a study on nanotechnologies and CSR in the F&FP sectors. However, after an extensive review of the literature, it emerged that ‘responsibility’ pertaining to nanotechnologies is ambiguous, and therefore ‘responsibility’ pertaining to the technology required investigation beyond the individual corporate entity. With a ‘reincarnated’ understanding of the issues, including the complications of regulating nanomaterials in F&FP, I resituated this study to include the perceptions of ‘responsibility’ among a heterogeneous group of actors. However, with the internationalisation of research activities, it would have been impractical to develop a single country-specific approach for a technology that is growing across borders. As the issues have become international, it is essential to avoid our understanding of what it means to be ‘responsible’ solely from the perspective of a developed country or by simply applying concepts of responsibility from developed countries in developing countries/emerging markets. Thus, I chose to investigate these notions of ‘responsibility’ across two divergent countries (Canada and India) with potentially diverse regulatory settings, and different cultural contexts and framings of technology. Moreover, given limited research on the ‘responsible’ development of nanotechnologies in emerging markets, specifically India, and with much of the research on nanotechnologies focused to developed countries, the challenge was to investigate the notions of ‘responsibility’ in developing and emerging economies, and therefore contribute to a gap in literature in this area.

In Chapter 2, I presented the literature review, which provided a critical review on the existing perspectives of the governance of nanotechnologies. In doing so, the chapter demonstrated
many limitations and gaps in the existing associated literature. In Chapter 3, I provided a conceptual framework to analyse the empirical data and discuss the findings. Through this framework, I argued that the available literature and frameworks are insufficient to address governance of nanotechnologies in new and emerging markets with growing R&D in nanotechnologies and that notions of ‘responsibility’ among a heterogeneous group of actors and their framings of technology in different spatial settings are needed to understand and explain existing governance models for nanotechnologies in these regions. The conceptual framework therefore emphasised on the inclusion of ‘region’ (which is neglected in existing literature) as an important element of RI, besides regulation and responsibility. In Chapter 4, I described the methodology used, specifically qualitative comparative case study, to investigate the notions of ‘responsibility’. The chapter presented a detailed explanation of the research design and the various methods used to collect and analyse the empirical data in the two cases of my study. It also provided the limitations and challenges in collecting the data. Chapters 5 and 6 reported on the findings of this study in Canada and India, respectively. These findings were discussed in Chapter 7, which offered a comparative analysis of the perceptions of actors, as well as policy/governance contexts by which nanotechnologies in F&FP is regulated/expected to be regulated in Canada and India.

The differences and commonalities noted from the findings (Table 8) and analysis through this comparative study between Canada and India suggested varied notions of ‘responsibility’ and provided answers to this study’s research questions. While addressing my two research sub-questions-- (i) How is the ‘responsible’ development of nanotechnologies (for F&FP sectors) influenced by national regulation and governance regimes? (ii) How is the ‘responsible’ development of nanotechnologies (for F&FP sectors) shaped by the normative framing of technology (and their interpretation of what it is to be responsible) in each region? - differing perspectives of ‘responsibility’ pertaining to nanotechnologies in F&FP emerged from the study. Differences in institutional structures in the two regions provided varied motives for R&D and nano-marketing. Thus, F&FP products were seen to be openly marketed in India, while in Canada, industry was seen to be afraid to disclose any use of nanomaterials because of fear of public activism and subsequent reputation damage. This answered my third question - “How do notions of ‘responsibility’ and regulation affect different geographies and markets for nanotechnology?”
8.1.2 Aim/Objectives of the research

The overall objective of this research was to investigate the notions of ‘responsibility’/RI as perceived by actors in the nanotech F&FP industry in two distinctly diverse regulatory regimes, Canada and India and to generate an empirical study.

Nanotechnologies in F&FP are complex as it entails the entry of the technology at any point within the food chain, whether the technology is used in food for safety, texture, flavour and nutrition, or in packaging to enhance the shelf-life of food and to detect pathogens at an early stage in food products, or even in agriculture to provide nutrients to crops using nano-sensors. Moreover, F&FPN involves the participation of a mixed group of actors, along a food chain that extends on a global level. In the absence of regulation of nanotechnologies, it is difficult to determine which of these actors, that may include (but not limited to) scientists, farmers, regulators, advocates, civil society groups such as NGOs and consumer representative groups, retailers and industry lobbyists, are responsible for the safe and ‘responsible’ research and development of nanotechnologies.

However, due to the highly polemic, polarised and emotional debates on GM foods in the media, evaluation and promotion of new technologies has become challenging as any new technology is looked at with suspicion, especially if these are associated with food. The literature review and the empirical data found many of the actors, especially those producing and manufacturing F&FP products to be cautious in disclosing their activities surrounding new technologies, such as GMO and nanotechnologies. Although it is the legal responsibility of producers and users of nanomaterials in F&FP to ensure that the food and packaging that they put in the markets are safe and comply with all applicable legislations, the complexity of nanomaterials renders such onus obsolete. However, there is an unwillingness also by other actors in the food chain to acknowledge their individual ‘responsibility’ pertaining to nanotechnologies, especially where food is concerned as it directly impacts human health and well-being. This thus raises the question, ‘who is responsible’ for the safe and ‘responsible’ development and governance of nanotechnologies? If actors are unwilling to acknowledge their individual responsibility, who do they perceive is responsible? And do they understand ‘responsibility’ pertaining to nanotechnologies? In order to address these questions, it was important to understand the notions of ‘responsibility’ as perceived through the lens of actors.
The empirical evidence suggests the notions of ‘responsibility’/RI is dependent on the perceptions of actors based in different ‘spacialities’ of innovation. Regulation, ‘responsibility’ and region were the three dimensions that were used to investigate perceptions of ‘responsibility’. The results showed that perceptions of responsibilities in two asymmetrical national regulatory settings, Canada (an OECD country) and India (a non-OECD country), differed.

Varied forms of ‘responsibility’ in nano-innovation were revealed through qualitative investigations in two regions with dissimilar institutional settings, through: (i) multi-stakeholder deliberative dialogues involving scientific, institutional, and industrial communities and the public; (ii) support by government in domestic R&D to help steer industry into commercialisation and stimulate economic growth and development; (iii) introduction of standards and policies through collaborative initiatives with international regulatory committees to establish new markets for nanotechnologies; (iv) putting trust on scientific expertise, NGOs and responsible businesses for the ‘responsible’ development of nanotechnologies; (v) focus on socio-economic needs of the nation; (vi) globalisation and internationalisation of collaborative EHS projects between developed and developing nations; and (vii) consumer choice where attitudes towards nanotechnologies are framed by celebrity advertising and media. Chapter 7 further summarised these distinctions. In the following sections, the implications of these findings will be discussed.

8.2 Conclusions

8.2.1 Diversity in interpretations of ‘responsibility’

From this study, we have seen that notions of ‘safety’ and ‘responsibility’/RI can be very nebulous and have different interpretations of what that can mean. The intention of this study was to interpret the meaning of ‘responsibility’/RI based on actors’ normative understanding of the term. It is a very relative term and this study showed that there were different approaches to the idea of RI in the two regions, and that the perceptions of ‘responsibility’/‘responsible innovation’ were different within these regions with diverse regulatory settings. These different normative understandings set the stage for how nanotechnologies are developed in the respective countries.
India is one of the fastest growing economies. As the second largest populous country in the world and expected to overtake China as the most populous country by 2050, India struggles with issues of poverty, nutrition and food production. India is also heavily dependent on its arable agricultural land. With growing population, climate changes and poverty, the Indian government’s main goal is to increase agricultural productivity and reduce poverty. Thus, the use of nanotechnologies is seen as a means to limit the likelihood of food production issues in India and address the various social issues in F&FP and agriculture that are predominant in such developing/emerging countries. The perceptions of actors in this study indicate that it is considered a ‘moral responsibility’ for researchers and entrepreneurs, including large firms, to develop solutions to provide socio-economic benefits to people in the poorer sections of society. There is greater attention given to the ‘moral responsibility’ of actors to find resolutions (using new technologies) for existing grand challenges that are seen as most pressing issues. For example, providing clean drinking water using innovations in nanotechnology as against dirty/muddy, bacteria-ridden water are perceived acts of ‘responsibility’. According to WHO, over a billion people do not have access to clean drinking water in developing countries, two million of which die due to water contamination. In India providing clean drinking water, especially in rural regions, remains a major infrastructure and public health challenge for the government. This is compounded by poor electricity infrastructure. Thus, a quick, easy, cost-effective solution where drinking water can be purified using potable water filters with nano-particles, which does not require additional energy (electricity or fire), is a welcome advantage for those living below the poverty line. New technologies that solve decade long problems cost effectively are embraced by both the citizens and the GoI. Such thinking thus drives the focus on the benefits for society rather than on issues of nanotechnologies that have so far shown no evidence of immediate danger to society.

A similar understanding of what RI means is seen in biodegradable nano-film for packaging of mangoes that can prolong the shelf-life of mangoes. The nano-packaging film is expected to provide farmers with a solution to stop deterioration of the fruit as it is transported from the farm to the markets, therefore improving the possibility of maximizing income. Such potentials attract farmers to use new technologies that can solve some of their basic social needs. Once again strong emphasis on societal values play a key role in understanding what it means to be

‘responsible’ and priority is given to the social benefits that can be sourced by the use of nanotechnologies.

Thus, nanotechnology is identified as an important contributor of meaningful solution towards addressing the MDGs and brings a lot of ‘hope’ for such rural communities in India, where there are pressing needs of clean drinking water, food security and poverty alleviation. In the lens of actors in India, such societal issues are of greater importance to a poor nation and the use of nanotechnologies is seen as means to finally address them.

While the above examples do attempt to validate the use of nanotechnologies, there is a danger, that such views are being shaped or superseded by commercial motives and underlying competitive interests of corporations and the GoI. It can also be argued that other (safer) technologies can be used to meet social challenges, though some may argue that these may not be as effective.

Moreover, while such unique models appear to bring new technologies to field and replace traditional redundant technologies, the understanding of potential risks affiliated with nanotechnologies may not be entirely comprehended by farmers that are uneducated. To them the idea of getting more income from the use of this new technology that promises results can be more attractive than a livelihood stricken in poverty. However, the danger is that the losses from any potential risks that may occur in future will eventually be borne by the poor farmers, as was seen in the case of genetically engineered crops when farmers committed suicide due to losses from crop failure and huge debts that they had incurred from purchasing GM seeds. Hence, there is a need for a precautionary principle to be applied in the R&D and implementation of nanotechnologies in India. However, such a cultural and developmental environment, where the framing of (nano) technology is based on providing solutions to social problems, hinders the adoption of the precautionary principle. If ignored, this could hamper India’s ability to ensure ‘responsibility’ in the development and commercialisation of nanotechnologies.

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72 For example, for water purification, reverse osmosis, sedimentation, membrane filtration, UV disinfection, ozone disinfection, distillation, are processes also being used to purify water. Most conventional forms of water purification used by the majority of the population, such as boiling, use of filters, chemical treatment, among others, are also largely ineffective in removing contaminants in water (Vijaya Lakshmi K. et al. 2011).
The notions of ‘responsibility’ in India is also framed around various arguments such as use of ‘natural’ or ‘organic’ nano-solutions, tried and tested materials (as those used in Ayurveda) and certifications by national and international organic food bodies. While certifications by a third-party entity gives credibility to new technologies and helps in meeting certain levels of standards, certifications that are usually used for accreditation of organic or macro-scale materials are questionable and (mis)used as a warranty for safety of nano-scale materials, resulting in many nano-products to be placed in the market without adequate tests. The purpose is to instil a perception among buyers that since they are certified, they are safe. It has been seen that apprehension towards innovative foods is often derived from uncertainty about the ‘naturalness’ of such products. Thus, perceptions of ‘naturalness’ or ‘organic’ is considered to be important for the social acceptability of new innovations in food. As the terms ‘natural’/’organic’ have a very positive connotation, its use on products triggers positive attention and trust in the product. Not surprisingly, using the term ‘natural’ in nano-based F&FP products is expected to create a perception that the product is ‘natural’ and therefore safe. However, while some nanoparticles can have natural origins, the stress on the term ‘natural’ diverts attention away from scientifically grounded efforts that are needed to ascertain their risks. There has been insufficient scientific exploration of naturally occurring nanomaterials (Sekhon 2010) hence caution needs to be practiced before tagging nano-based F&FPA products as ‘natural’. However, it can be suggested that the identification of ‘safe’ and ‘natural’ nanomaterials will be a crucial aspect for the acceptability of nanomaterials by consumers, especially in the Global North, where innovations in food is less accepted.

In contrast, the notions of ‘responsibility’ in Canada lean more towards prevention of risks. Canada places a higher social value through economic, social and environment well-being of the community. With mounting disasters in the food industry within Canada due to contamination and other issues, there is growing attention by food companies to incorporate solutions that can protect consumers from such issues. Here, safety is given precedence over social needs. This is evident in the way Canada regulates its existing food industry through the incorporation of stringent laws and legislations for food, including novel food products (see Chapter 5, section 5.3.2). ‘Responsibility’ is seen as embedded in the system in Canadian institutions where people working on innovations are bound to a code of conduct that is consistently focused on ‘responsible’ and ethical practices in research.
These differing perceptions bring forth a new understanding of the way ‘responsibility’ in innovation is perceived and practiced in international territories. While on the one side there is huge uncertainty on the safety of nanotechnologies and the need to protect society against future potential risks, the other side points to a deeper situation where there are more pressing challenges of food security, nutrition for the poor and poverty alleviation, which could be mitigated by such new technologies. On the one hand, it can be argued that there are as of yet no disasters from the use of nanotechnologies. On the other hand, some may also argue that other ‘safer’ technologies can be used, instead of nanotechnologies. Whether these differences in perceptions are based on different cultural understandings of ‘responsibility’ as perceived through the lens of actors or the institutional structures within the regimes, whatever the inference, it will certainly have an impact in the way markets are constructed for nanotechnologies in Canada and India, and thus cannot be dismissed.

However, it cannot be ruled out that these variances in perceptions of RI implies that the conditions in which nanotechnology is developed in less developed countries can be very different to that in developed countries. As has been seen, the ‘responsible’ development of nanotechnologies for the F&FP sectors is shaped by the normative framing of technology (natural, organic, etc.) and their interpretation of what it is to be ‘responsible’ (benefits for society, safety in food) in each region. This essentially means that different institutional and cultural settings have different ideas of what it means to be ‘responsible’. The rational that by simply applying the Western concepts of responsibility to an emerging economy can lead to ‘responsible’ behaviour and practice can thus be misleading and lead to incorrect interpretations and perspectives of ‘responsibility’ when considering an emerging economy. This can result in many failures in instilling ‘responsibility’ in these developing economies when this regional context of what it means to be ‘responsible’ is neglected or ignored. This emphasises the need to take into perspective ‘region’ when designing frameworks for regulation and RI.
8.2.2 Influencing responsibility through stringent regulations and stakeholder participation

8.2.2.1 Stringent regulations

Most developed countries have strong institutional structures that keep in check and monitor markets to ensure safety of food products. While Canada does not have specific regulations for nanotechnologies in F&FP, relevant governance strategies can be found in existing policies and guidelines in food. In Canada, the findings indicate a governance landscape that incorporates a number of regulatory measures, including: inclusion of a heterogeneous group of actors in policy discourses; regulatory reviews concerning the safety of existing nanomaterials in the DSL; the use of existing highly stringent laws for F&FP as regulatory sufficiency for nanomaterials; a set of criteria for funding, which includes ‘responsible’ practices and biosafety tests; mandatory reporting for import and production of nanomaterials greater than one kilogram; and the incorporation of EHS and ELSA (ethical, legal and social aspects) research for the ‘responsible’ development of nanotechnology. Through these measures, the Canadian government and regulatory agencies highly influence ‘responsibility’/RI by setting robust rules and regulations for F&FPN.

The GM case as well as numerous food catastrophes in Canada has necessitated the regulatory agencies to maintain the imperative for establishing stringent standards for F&FP. The affinity towards the adoption of such stringent regulations in food demonstrates that Canada is a highly risk-averse nation. This encourages ‘responsibility’ on the part of corporations that are also fearful of implications of reputational loss and public backlash.

Various conditions of governance are also implemented by setting certain criteria (such as rigorous biosafety tests) for funding of R&D of nanotechnologies, both nationally and internationally (as seen in the Mango case study). Findings also show that parties conform to regulations within their respective region but work on negotiated and varied understandings of responsible innovation. This condition also raises the safety standards in regulatory decisions on new technologies like nanotechnologies on an international level. It highlights Canada’s understanding of what RI really means and how these understandings are implemented through regulatory instruments and technical practices set by the government. These conditions of governance set by the Canadian State suggest that ‘responsible’ development of technologies
(in this context nanotechnologies) for food and food packaging sectors is influenced by national regulatory and governance regimes (which answers the first question of my research).

However, while these criteria highlight the stringent requirements by which the GoC governs nanotechnologies, there are many loopholes in this initiative which needs critical review. First, it can be argued that some of the projects on risk assessments of nanotechnologies are ad-hoc and are not sufficiently funded. Second, these projects are constrained by time and are required to be completed within a timeline, which may not be sufficient to assess the entire lifecycle of a nano product. Third, in the absence of a globally defined biosafety test for nanotechnologies, such tests can be disputed. Though tests are carried out at advanced government-approved testing laboratories and agencies, the expertise and protocols for testing nanofood products is still absent/not defined. Moreover, such tests require advance instruments and skilled manpower, which can be an added cost for large companies and unaffordable for smaller firms and entrepreneurs, especially start-ups. This highlights further challenges in the ‘responsible’ research and development of nanotechnologies, where there is a danger of companies skipping these tests. Fourth, though there is a criterion for biosafety tests, the funding bodies have no way of knowing or checking whether these tests have been carried out, especially if these are carried out outside its own jurisdiction. It is left to the recipients of the grant to ensure that they carry out the tests. Under these various circumstances, there is a likelihood that nanomaterials and nano-products can skip through the current safety net.

Further, while such stringent regulatory structure does lead to a better management of the type of products that enter Canadian markets and potentially provides Canada some protection from the future hazards of nanotechnologies, it has also extensively restricted innovation resulting in many research activities moving to competitive, more ‘friendly’ regions like the U.S., where policies are less stringent, as was evident from this study. This potentially means that Canada is probably losing out on competition and economic advantage. Further, while the regulatory structures are a source of control over the activities of food companies, progress in establishing greater transparency from organisations has been pitiful. The empirical evidence shows companies denying any research on nanomaterials, even though there are ongoing R&D in their organisations and at universities. It can also be pointed out that these stringent regulations have reduced the demands for regulations for nanotechnologies from companies, in contrast to the demands that were voiced by innovators in India. This is ironical considering companies in
Canada are secretive of their activities in nanotechnologies in F&FP while those in India are ‘transparent’ and open about it.

Further, though such stringent laws exist to cover governance of nanotechnologies in the F&FP industry in Canada, these regulatory mechanisms do not guarantee the elimination of potential risks associated with nanotechnologies. Additionally, it would still be a challenge to monitor every point of entry and exit of products into markets. For example, it would be impossible to inspect every package that came in at post offices, or check every container at all ports for nano-based products and substances, or monitor every online purchase that is made, unless there is inside information that is provided to alert authorities. It is thus expected that those researching, producing, manufacturing and using these nano-based products and materials, go through the appropriate government agencies for approvals or apply appropriate safeguards, such as the traditional precautionary principle, to ensure safety of these F&FP products. While, novel foods warrant submission of information pertaining to new ingredients in products in Canada, these regulatory instruments can only be effective based on the moral responsibility of companies to be transparent in their disclosures. However, though companies are legally responsible for the safety of their products, it is difficult to monitor their activities and ensure that they are behaving responsibly, especially when they operate in trans-national territories where the regulations may be poor or weak. The responsibility of such organisations, especially those from OECD countries, would be to ensure that what they introduce in these poorly regulated regions are on par with the regulatory protocols that they would follow in their own countries, for example, as we currently see in the medical practice. It will also be the responsibility of intermediary actors such as NGOs – whether global or local – to keep an eye on such multinationals that may want to deviate from their responsibilities. Therefore, by setting these stringent standards within its local processes, it can be suggested that Canada, in a way, influences its high standards on international regulatory systems whether through its participation in regulatory processes at the ISO/OECD level, or through enforcement of its practices on suppliers that may be based in a different country.

8.2.2.2 Encouraging multi-stakeholder dialogues

In keeping with the lessons learnt from GMO, where non-communication with the public has led to much activism, in Canada, various actors are invited to participate in multi-stakeholder
discussions on the issues of nanotechnologies. Such early consultations during policy-making processes with the participation of key actors across business, government, CSOs/NGOs, scientific community and academia to discuss safety issues of nanotechnologies will help to address understandings in safety issues, recognize impending impacts, facilitate further EHS research and initiate regulatory discourses early on. These engagement exercises with polemic stakeholders is also expected to help assuage some concerns in Canada and enhance transparency in the R&D of nanotechnologies, allowing CSOs/NGOs to bring forward any concerns that they may have with regards to safety issues of nanotechnologies and giving firms and innovators an opportunity to provide relevant information that would allay any concerns that may be raised. It also allows the State to be kept informed of the issues and progress of nanotechnologies in society, which in future can be expected to lead to better policies.

However, it can be debatable whether in practice the views of CSOs/NGOs that participate in these deliberative processes are actually being incorporated in policy decisions in Canada, considering the government is biased and in favour of the commercial interests of the industry when making policy decisions. Many of the CSOs/NGOs had pointed out in the interviews that their voices were often drowned in the presence of these powerful actors and innovators. Often these public representatives work alone and with low budgets. It is therefore not surprising that they are outnumbered in their views and are often under-represented in such deliberations due to lack of funding for travel to these meetings. However, the evidence from this study shows that approvals for many technologies in products can take up to ten years to be approved by regulators, even though these are passed in other OECD countries. This finding highly contrasts to the thinking that the Canadian government is biased towards companies.

8.2.2.3 Involvement in international regulatory committees

The way to govern the risks arising from nanotechnologies is full co-operation among various nation states, including between developed and transitioning/developing countries. The involvement of states, both developed and developing nations, in international policy discussions/debates is not only important for sharing and understanding the issues of governance of nanotechnologies but also contributing to policy debates and developments for setting basic standards for nanomaterials and products.
Canada is actively involved in international collaborations on such initiatives as the ISO and OECD. The idea of such international voluntary initiatives for nanotechnologies is quite exclusive where countries collaborate to establish mutually-agreed standards, rather than each country developing their own standards and regulations. Under conditions of uncertainty, these internationally-driven initiatives provide a coordinated response for the governance of nanotechnologies. Corporations, too, seek a globally accepted regulation so as to be able to benefit from exporting from one country to another without having to adapt their products based on an individual country’s regulatory needs. Thus, the active involvement of Canada in the development of such regulatory measures is expected to provide ease of trade of nano-based products across nations. Such internationally agreed approaches are also expected to provide the knowledge that can be adopted by individual countries to create their own regulatory measures, such as the CSA Z12885 (which is a revision of the ISO Z12885), a guidance for safety at the workplace, which was developed by Canada as a consequence of their involvement with the ISO committee on nanotechnologies. The deficit and tangible gaps in expertise and resources from diminished budgets due to austerity measures (as evidenced in this study) are also reduced through the involvement of Canada in such international regulatory committees where regulatory frameworks/programmes are being developed and shared with experts from other states.

However, there is, as yet, no agreement on a common definition on nanotechnologies at a global level, so enforcing any regulations for nano-products across international boundaries with different regulatory settings can be challenging, especially in developing countries/emerging markets, where the regulations are often low or limited. Moreover, this study found that there are other political agendas in the ISO committee, where each country wants to enhance its economy and hence there are power struggles that exist between countries to push certain nanomaterials than others. Unfortunately, such power struggles can cause further delays in regulation and impending progress in establishing a common definition for nanotechnology, which could hinder progress and mitigate potential trade opportunities in future. Thus, countries like Canada are establishing their own regulatory structures to enable effective and ‘responsible’ commercialisation of nanotechnologies across borders. For example, the Canada-U.S. RCC initiative is expected to provide bilateral regulatory cooperation and alignment for nanotechnologies, which will basically make it easier for nano-based goods and research activities to be monitored across borders through defined rules and regulations. The importance
of advancing bilaterally through such agreements as the RCC will be essential to the future governance of nanotechnologies across porous borders, though it is questionable about the focus of such initiatives considering the U.S. is much more leaned towards commercialisation of nanotechnologies.

Furthermore, the OECD WPN is voluntary, hence it can have quite an impact on what it can do and what the different roles various countries can play. A lot of its work is in kind so the countries that participate in various activities carry out work in their own laboratories. Thus, some countries have more money and resources to put into it than others, a reason why perhaps India, with other social priorities, refrains from actively participating in these programmes. Additionally, when regulations are discussed and prepared at a global level through such initiatives as the ISO and the OECD, it starts entering a political process where powerful industrialized countries ultimately shape these regulations. Hence, countries like India, with its varied expertise and outlook that try to export their domestic vision onto such platforms might be a minority voice, even if it is the voice of reason. Thus, the role of non-industrialized countries in such international regulatory or governance processes may be constrained by certain power structures within the process and can be limited by their place in the pecking order of this larger international framework. Hence, while India and Canada are seen to be involved in various international working committees for nanotechnologies, we find that Canada’s participation is much more pronounced and participatory as leading in some of the major activities, whereas India was not as visible and participated mostly in ‘absentia’. This absence of an Indian presence in international (risk) discourses is perturbing. Their participation is essential to provide inputs from a non-Western understanding, considering countries like India play an important role in the global export market for food. With emerging economies expected to have a major share in global market, it is essential that such transitional countries (like India) are included in global nano-policy debates and discussion. This is because if these technologies have the potential devastation that many believe they have, the location of future risks (if any) in India can have huge consequences in other countries with goods constantly being traded. Thus, countries like India need to be at the forefront and actively involved when developed regimes are designing the policies for regulating nanotechnologies to ensure legitimate handling of public concerns that may occur due to products being placed in the markets in India, and to avoid a GM-style backlash. India too, must make more effort in participating and contributing to the global nanotechnology discussions through such
committees. Further, Canada has established the regime of OECD countries that requires high standards and regulations. Often the license for products approved and sold in developed countries, such as the Certificate of Free Sale\(^7\) issued by the GoC, stands as a declaration of the safety of the product when viewed by other countries. In contrast, India as a BRICS nation, though an important emerging market, is still tagged as a nation with low or limited regulatory regime. In order to compete in the global market, India must ensure that it is seen as participating in such deliberations if it wants to establish future trade links for F&FPN with these countries that have high standard requirements.

8.2.3 Addressing issues of EHS and ELSI

In both, Canada and India, we saw a growing interest in EHS and ELSI, largely initiated from the lessons that were learnt from past similar technologies applied in the food sector, such as GM foods and irradiation. While in Canada, the perceptions of safety, embedded within the food system, have driven actors to consider such issues early on by establishing various centers for addressing the EHS/ELSI, in India, there is limited but growing awareness of the issues of nanotechnologies, which are largely being driven through collaborative projects with developed countries and the potential of commercial opportunities. The acknowledgement of the need to address the safety issues of nanotechnology has also been reflected in the early development of the guidelines for the safe use of nanomaterials in the laboratory in both, Canada and India. While such guidelines cannot be a substitute for national laws and regulation for F&FPN, and is only voluntary, it is a good ‘starting point’ for the governance of nanotechnologies and for further development of regulatory measures in future. Moreover, adopting such guidelines of safe handling of nanotechnologies manifests the positive intention of both countries to show attention to the EHS issues of nanotechnologies, considering both countries are keen to take advantage of the potentials of nanotechnologies. Such moves also re-emphasise the significance of local mechanisms for the governance of nanotechnologies, especially in developing countries. By developing local mechanisms, it avoids having to constantly rely on the U.S. and EU to develop regulations (the empirical evidence showed that India never develops its own regulations but usually imbibes regulations that are initiated from

\(^7\) A document provided to manufacturers, which certifies that the specified imported goods are being sold in the exporting country's markets and are permitted for export; it is required in certain countries or for certain commodities
other nations – see Chapter 6, section 6.3.4) or the international community that could take time in coming up with regulations. The formation of the guideline is especially a huge development for India that has always come under scrutiny for its low regulation by the West. There is a conservative view in the West that developing countries do not have high standards, and have no such tradition of ‘honouring’ the law as it is seen to be ‘optional’; and if there are laws they have ‘no teeth’ and so people tend to disregard the laws. Though it can be questionable whether these enactments of ‘responsibility’ are likely to be embedded in other programmes within India, there is evidence that India’s attitude is changing as it is keen to trade in the global market. As seen from this study, there is a lean towards the North American or European model for ‘responsible’ research and development of nanotechnologies where high standards and biosafety tests were negotiated and carried out to meet requirements set by developed nations. This willingness to incorporate certain ‘responsible’ practices, through negotiations with the West shows a lean towards a RI approach and in promoting the ‘responsible’ development of nanotechnologies in India. Further learnings from abroad are being transferred into India where certain ‘responsible’ practices (if not all) are being incorporated into various research programmes through scientists who were either educated abroad or received some form of training in a developed country on nanotechnologies, including EHS/ELSI.

Thus, from the above examples, we can infer that ‘responsible’ EHS and ELSI-related practices are being driven by such highly regulated developed countries into less regulated emerging markets. Though the concept of precautionary principle has not as yet taken precedence in India, these alliances with an international community demonstrate India’s keenness and ability to study and carry out risk assessments of nanotechnologies. Such collaborations can therefore have many implications for India: First, as well as the potential of an international market for these nano-products in future, Indian scientists will largely depend on these collaborative international projects to bring in the much needed investments from developed countries for biosafety and nanotoxicity tests, which will be essential to curtail the deficit in resources for nano-biosafety research. Second, the criteria set by these developed countries for nanosafety tests is likely to drive high standards into India, increasing the potential for India to compete in the global market. Third, such collaborations on nano-safety will be seen positively by the West and can thus increase India’s ability to create a ‘level-playing’ field within the global nanotech market in future. However, the notions of RI in India are different (as discussed in section
8.2.1) and needs to be taken into perspective before applying Western practices and regulations in such developing countries.

Another key finding from this study points to transnational collaborations on nano-risk research. The study found various interesting cases in India where numerous biosafety tests are being carried out in collaboration with international institutes in developed countries to study the risks of nanotechnologies. This implies that India is an obvious partner for testing of nano-based products for biosafety. This may be mainly because of the availability and freedom of researchers to carry out certain tests, such as those on animals, which are restricted in developed countries like Germany, as found in this study. However, the use of India as a ‘guinea pig’ by the West is not uncommon; past cases of testing drugs on people in India by pharmaceutical MNCs is but one example. Thus, the main concern is not whether India has the aspirations, capabilities or infrastructure to study the toxicity of nanomaterials, but that it can be used as a ‘dumping ground’ and ‘guinea pig’ to carry out tests using new technologies, like nanotechnologies, without proven safety tests, especially by companies with profit-making interests. These circumstances make India vulnerable to nanotechnology risks and illustrate the need for caution on all sides. Consequently, India needs to be wary of these irresponsible agendas in its quest for technological advancement and the GoI should play a significant role in creating regulatory measures that will discourage such misuse.

The importance attributed to risks of nanotechnologies can also be mirrored in the allocation of research resources towards nanosafety tests, as well as discussions surrounding them. It is obvious from the findings in Canada as well as India that current research programmes on EHS and ELSI are not sufficient compared to the total amount of investment in R&D of nanotechnologies in both regions. Thus, despite the growing investments in R&D in both jurisdictions, the risk research underpinning this investment is weak. This can lead to decreased knowledge in safety of products and an increase in uncertainty due to increased R&D in nano-based F&FP products. Thus, though this study indicates that ‘responsibility’ pertaining to EHS and ELSI are recognised as important issues, it is not as yet, as big a priority (compared to commercialisation) within the Indian and Canadian governments. This could increase knowledge gaps and further delay regulations, which is currently seen to be largely detrimental and disruptive for innovation and commercialisation of nanotechnologies. Therefore, there needs to be a balance between huge investments in R&D for commercialisation versus those
in EHS/ELS aspects. It is crucial that essential funding is diverted towards EHS/ELSI research so that the benefits of nanotechnologies can be realised early on.

This study also highlighted some disconnect in sharing of nanotoxicity data between the international scientific community and India, which further aggravates risk issues from India. A consequence of this absence in communication is currently already seen in the export of nano-based F&FPA goods to developed countries from India. A harmonization of data on toxicity from across the world is essential to expedite the validation of nanomaterials. Data-sharing from developed countries with developing countries, and vice versa, will not only build a harmonised repository of available information on the risks of nanotechnologies and better understanding of the issues, but it can also avoid duplication on research that may already have been carried out in other parts of the world and is likely to be crucial to both, OECD and non-OECD countries’ responses to risks in future. Moreover, a collaborative partnership for studying such issues of nanotechnologies is necessary if both jurisdictions (developed countries and developing countries) want to establish trade partnerships in nano-related products in future. For OECD countries, such partnerships would also provide the surety of ‘safe’ (nano) food products that are being imported from such developing/emerging countries. With border control a humongous challenge, as evidenced in this study, the entry and exist of nanofood and packaging products can be controlled with early intervention and knowledge-sharing on nanotoxicity research.

While I make the argument that India is making efforts to address the risks of nanomaterials on a case-by-case basis, however, India is still vulnerable to the future risks and catastrophes that may arise from nanotechnology due to the accelerating advancement in nano-products in the region. Whether India would be able to cope with future risks is uncertain, mainly due to its large population and inability to control penetration of products into the market. This study shows that, whilst scientists and government authorities appeared to recognize the importance of risks associated with nanotechnologies in Canada and India, the sale of various nano-products in the market in India, displays inadequate use of caution in the commercialization of nano-products by the government. Though most government officials appeared to be unaware (and almost indifferent) of these nano F&FP products in the market (despite these being openly sold, advertised and covered in the media), the empirical evidence indicates that many of these products are being developed at government-led institutions. Such government ‘endorsement’
of nano-products has run the risk of the government’s ‘approval’ of nano-based products, giving firms the green signal to freely develop, manufacture and sell products in India and abroad. This could lead to industry negligence and malpractice. In their enthusiasm to create innovative products and gain competitive advantage, and without a comprehensive regulatory system in India to monitor compliance of legislations, it could also lead to the industry fabricating safety data (even calling it ‘natural’ as seen) in order to be able to get product acceptability. In the absence of sufficient information on the risks of nanotechnologies, such aggressive entry of products in the market and lack of precautionary measures could result in a potential disaster and greater risks for consumers and environment in the region, and the inability of the government to control or withdraw such products from the market in case of risks in future.

The Indian State’s response to the potential risks of nanotechnologies appears to be slow or nonchalant. There appears to be a lack of involvement and enthusiasm by the government in initiating any approach towards RI. This suggests that the enthusiasm for nanotechnologies and the potentials of the technology for societal needs, far exceeds the concerns. As a government official pointed out, action is only taken when a disaster happens. So is the GoI waiting for a disaster to happen before it takes more steps? This indicates another form of a ‘waiting game’ scenario, where the complacent attitude of the GoI can only infer that actions will be taken as and when a catastrophe happens. With India’s late entry in the nanotech scene, it appears that the GoI’s focus is on ‘catching up’ on R&D of nanotechnologies that is expected not only to provide great benefits for society but also to provide benefits of patents and commercialization of products in future. Though the Nano Mission committee has been set up by the GoI, the committee is largely involved in propagating R&D/commercialisation of nanotechnologies and risk assessments in the Mission’s national strategy have largely been neglected. The lack of attention and insufficient funds have also delayed research in EHS/ELSI, leading to unregulated products entering Indian markets at a faster pace than any form of regulation being put in place. Additionally, smaller firms without access to government resources and facilities, (unlike public institutions), may skip advance and expensive biosafety tests that might be needed to test the safety of nanomaterials in their products. The proliferation of untested products in the market can lead to future problems through unforeseen catastrophes or could result in an ‘out of control’ situation for the GoI with no regulations in place, nor a ‘heavy hand’ to keep a check on such activities. Further, these potential risks have the propensity to
be extended to other continents where these products are exported. The influence of the Global North in initiating such R&D and products of new technologies cannot be ruled out. The demand for products and promises of a huge market, largely propagated by the West, is an influence for such BRICS nations, like India, in wanting to get a share in the market or capture the potentials and opportunities from these technologies. However, greater effort is needed on the part of the GoI, either through the provision of much-lacking fund or through greater involvement in global deliberations, to encourage and propagate EHS research and ‘responsible’ practices alongside nanotech R&D efforts. The GoI must also make strident effort to encourage the adoption of the precautionary principle among innovators in government institutions as well as firms.

8.2.4 Role of intermediaries in responsible innovation and nano-acceptability

In addition to the regulatory initiatives led by the state and government bodies, the empirical study suggests the role of various non-state actors and intermediaries as essential to the process of ‘responsible’ development, implementation and democratization of nanotechnologies. This study has identified that perceptions of acceptability are defined through the participation of various actors, such as NGOs, media and celebrities, in the governance and RI of nanotechnologies.

8.2.4.1 Identifying the role of CSOs/NGOs in responsible innovation

It is essential that F&FP products that are developed need to be very safe and proven safe before they are launched in the market as any catastrophes can have drastic implications for public health and safety, as well as for the innovation. We have seen significant consumer activism in certain technologies that have been introduced in the past, especially in food (e.g. irradiation, GMO), because it is so ‘personal’. The opposition to N&N is mounting and expected to continue to grow, especially against the backdrop of the GM debate, which continues to cast a shadow in the background. The findings from this empirical study indicate various references to an analogy with GM foods, a technology with similar hypes for benefits but which failed to yield expected results. It is obvious that the debate on unwarranted future impacts of GMO has created some fears about the risks of nanotechnologies among people. Thus, avoiding nanotechnology becoming ‘the next GM’ is seen as critical to the final acceptability of the technology in both Canada and India. Therefore, the ‘lessons’ from the GMO debacle has
caused various actor groups, including scientists, regulators and firms, to be cautious about how they proceed with nanotechnologies.

Under these polemic environment, the inclusion of CSOs/NGOs, the voice of the general public and with some knowledge of nanotechnologies, can be essential to the ‘responsible’ governance of nanotechnology. This study has indicated that CSOs/NGOs have an important and ongoing role in the ‘responsible’ development of nanotechnologies. The empirical study indicates significant contributions of NGOs in shaping nanotechnology’s development trajectory in two distinctly diverse regulatory settings. The influence of NGOs is seen not only from the perspective of ensuring/monitoring health and safety for society (as activists) but also from the perspective of their societal contributions in advocating new technologies where it is most ‘needed’ (as promoters).

One of the most significant findings to emerge from this study is the involvement and use of NGOs (in this case, those that are not activists but ‘evangelists’ of new technologists) by (trusted) scientists in promoting nano-based products. through constructive communication with farmers at the grassroot level. While the researchers anticipated much opposition from farmers due to earlier GMO issues, the early intervention of NGOs in the development process helped overcome some of the socio-technical constraints that existed in India and significantly enhanced the trust and confidence of farmers in nanotechnology.

While the NGOs in India are used as a stimulus to educate people and promote nanotechnology, in contrast, the engagement of NGOs in policy debates by authorities in Canada shows the importance of their substantive role in policy design and discussions, where their arguments and opinions are captured and integrated into policy-making processes. Unlike in India, the role of NGOs here is reversed where they are present as activists, bringing into attention the negative consequences of nanotechnologies, rather than its benefits. This is not surprising as there has been significant consumer activism in other emerging technologies that have been introduced in the past in developed countries, especially in food (e.g. irradiation, GMO).

The increasing number of backlash from activists (as in GMO) and subsequent boycotts of products by consumers show increased and ever-growing power of NGOs in the innovation process, which must not be ignored. Building relationships with such intermediary organizations that can have powers to impede innovation, which can lead to serious
implications for the trajectory of nanotechnologies, is important for regulators and policy-makers.

The inclusion of CSOs/NGOs in various national and international nanotech activities, including the ISO/OECD committee for nanotechnologies, also provides an insight into the growing importance of such entities in the ‘responsible’ governance of nanotechnologies on a global scale.

Thus, we find a model of governance that emphasises partnerships with NGOs in deliberations of regulatory governance (technology watchdogs, knowledge providers and regulation-enforcers), delivery of technology to rural areas (technology promoters), appeasing resistance (technology pacifiers) and training and educating farmers (technology educators). With a dual responsibility, as advocates and opponents of new technology, NGOs are expected to play an influential role: (i) against polarisation of nanotechnologies and the acceptability, adoption and implementation of nanotechnologies, and (ii) in nanotechnology regulatory debates where their sentiments will be essential to policy consideration and development for ‘responsible’ governance of nanotechnologies. The inclusion of stakeholders and their engagement at an early stage in the governance of nanotechnologies clearly points to a RI approach embedded within the innovation system in Canada and India. These initiatives are essential to help shape the governance structures of nanotechnologies where there is absence of regulation. These differences highlight the importance of taking into perspective the notions of ‘responsibility’ in developing and developed countries. Despite having symmetric values, these NGOs are seen to have different perceptions on nanotechnologies. I therefore argue that this contrast/difference in notions or ‘responsibility’ in developed and developing is essential when developing regulatory mechanisms and frameworks for RI. Therefore, the inclusion of region is an important dimension that must be considered when developing frameworks of RI.

8.2.4.2 Role of celebrities, media and organisation in responsible innovation

The role of celebrities is also important for the governance of nanotechnology. In the past, we have seen distinguished figures like Prince Charles deride nanotechnologies, which created much attention and controversy in the media and among nano-boosters. The empirical findings from India and Canada, have highlighted the important role of celebrities and eminent personalities in the promotion of nanotechnologies. The endorsement of nanotechnologies and
nano-based products through print and television advertisement by eminent celebrities (like David Suzuki\textsuperscript{74}, Dr. Oz and Amitabh Bachchan) and reputable and trusted firms (such as the TATA group in India) are essentially to build positive attitudes towards nanotechnologies and to instil a belief among consumers that the products from nanotechnologies are well-tested and safe to use. Such approaches to promote products of nanotechnologies will have significant implications in establishing trust among consumers and in creating a new market for nano-based F&FPA products.

These overt endorsements from well-known and well respected figures in society lead to framings of consumer perceptions of nanotechnologies. However, I argue that insufficient knowledge of such celebrities and notable figures on the risk issues of nanotechnologies can lead to misinterpretations and technology over-hype, which can have detrimental future consequences. Nevertheless, the participation of such actor groups is significant for future debates and market development.

8.2.4.3 Transparency of organisations

Openness/transparency is also an important and fundamental element of RI. In the past, various international NGOs have called for a moratorium on nanotechnologies until some form of regulation is put in place. Such public outcry by NGOs have deterred companies from openly discussing their research in nanotechnologies, especially in the West. Because of companies’ reluctance to discuss innovations in nanotechnologies, businesses in Canada appear to be less transparent and less positive in their discourses of nanotechnology as they wait for nanotechnology to be given technological acceptance (by the public) and endorsement (by government) through regulations. This has resulted in the industry being constantly scrutinized for its ‘responsibility’ in the governance of nanotechnologies.

However, the dilemma of producers and manufacturers, needs to be considered - the fear of societal backlash which could lead to consumer boycotts, and damage to firms’ reputations and their bottomline. With government being ‘silent’ on the use of nanotechnologies in F&FP, organisations are in a ‘catch-22’ situation. If they label nanotechnologies on their products,

\textsuperscript{74} Promoted nanotechnologies through the CBS television series “The Nano Revolution”
they may face public backlash (as with GM foods), however if they fail to recognize the potentials of the technology, then they could become less competitive. Thus, either way, they are likely to inevitably attract criticisms and suspicion among consumers and CSOs, and penalized for their activities as we have seen with previous emerging technologies. Furthermore, the backlash relating to food, is a reminder of the sensitivity of the sector. Under such paradoxical conditions, businesses choose to remain secretive about their involvement in the R&D of nanotechnologies. However, the lack of openness and ‘transparency’ from companies in Canada will most likely continue to magnify suspicions and distrust in companies and government (who support them for their innovations) and the technology per se, and further augment the role of activists in the ‘responsible’ governance of nanotechnologies.

Conversely, this study showed that organisations in India keenly and openly discuss R&D in nanotechnologies as an expression of their social responsibility towards society. Moreover, products incorporating nanomaterials were found to be openly labelled as ‘nano’. While this may not reflect transparency as we may perceive it, this characteristic can be attributed to various aspects: (i) firms are enthusiastic about their research focusing more on the benefits rather than the risks of nanotechnologies, and thus appear transparent about how they use nanotechnologies in their products. Therefore, through a general normative understanding that it can provide various benefits to society, companies in India, openly advertise their products through advertisements in television, radio and print; (ii) some firms are naïve in their understanding of nanotechnologies’ risks and unaware of the repercussions of their openness; their intention being instead to promote their products and research activities to the local and international audience to gain recognition and competitive advantage; (iii) there is a different understanding of innovation, where the ‘acceptability’ of new technology and innovative products among the general public is constructed through a technology hype created by the introduction of nano-labelled products; and (iv) risk debates have not as yet taken off as strongly as in the West and hence acceptability of nanotechnologies is based on the current framings of technology (as a good thing).

8.2.5 Creating markets for nanotechnologies

The findings suggest that the government, state and provincial agencies see a potential of a huge market in Canada and India. While in India, it is expected that the market for
nanotechnologies in F&FP, including agriculture, is likely to grow rapidly over the next decade, how that is going to work in Canada would really depend on the science and public reaction to the introduction of the technology in the food chain. Where product benefits outweigh the risks, for example in packaging and health products, it can be expected that such products will enter markets more quickly.

The future of markets for nanotechnologies in F&FP will also depend on path-breaking research and products. For example, the Canada-India collaborative research on nano-packaging film for mangoes could set the trend for commercialisation of packaging incorporating nanomaterials on a large scale. It may well be that within the next 1-2 years the nano-packaging will be used by farmers and exporters in India and Canada, thus opening up a new market for nano-packaging in the two regions, and beyond. This is because although regulators have ultimate authority over the contents of novel foods, it was pointed out by a policy-maker that submission of pre-market assessments for packaging is voluntary. This finding, as well as the various nano-packaging projects currently under development at Canadian universities, signify that nano-packaging may already be in the market, as also claimed by a scientist in a food processing that was approached with the product. In this respect, current stringent regulations for food may not be entirely appropriate or applicable for nano-packaging, under the current stance taken by regulators that regulations for nanotechnologies in F&FP is sufficient.

However, first, the market place has to be receptive to nanotechnologies. The R&D and sale of nano-based F&FP products will largely depend on demand in India and acceptability of the technology in Canada, keeping in mind that packaged food is not as popular in India due to easy availability of fresh and ‘natural’/organic produce and fear of modifications/’unnaturalness’ of food in Canada. Second, there is also the issue of product cost applicability. Where there are benefits of products of nanotechnologies, consumers in Canada may be willing to pay premium prices for high quality products with strong safety standards, whereas in India, consumers may be price-sensitive due to a larger proportion of the population living below the poverty line. Thus, pricing could be an essential factor in innovation trajectory of nanotechnologies in F&FP. Third, nanotech firms, especially smaller companies in India, will also have to find a way to overcome challenges of implementing nano-producing techniques on an industrial scale before being able to benefit from profits. It is obvious from
the findings that though smaller firms in India receive big orders for their products, they do not have the resources or capacity to manufacture large quantities and would require support from larger firms to take their products to market on a bigger scale. However, bigger firms, especially those with a large share in the market, are cautious about using new technologies that they do not understand because of their fear that the product might fail, though this might change in future when the benefits of nanotechnologies are better understood. In the meantime, the lack of sufficient understanding in the area is likely to deter some firms in India from using nanomaterials in their products.

Various factors can also limit development of nanotechnologies in these regions. For example, inadequate funding from government and banks for small companies and entrepreneurs in India can create challenging funding issues for nanotech development in India. There is also the challenge of transferring technology to industry. In Canada, low industrial investments in nanotechnology development in F&FP is because companies are dissuaded by the obvious challenges of production profits, public backlash and health and safety concerns. It is alright to support research at government institutes in Canada and India but if there isn’t the “pull” from industry or sufficient backing from government for commercialisation (in terms of assistance to take products to market or bring in legislations to guide/assist firms), then the technology will remain nothing more than a patent. Thus, such challenges can slow down development of nanotech F&FP products within the regions.

The use of nanomaterials in many of these F&FP, including agricultural products, also has many cross-border implications. India, as one of the fastest growing economies, and a BRICS nation, is welcomed as a trade partner with developed countries. However, in their enthusiasm to establish a market for nanotechnologies, India could end up cutting many regulatory corners and technological and policy cords. This was already obvious for mangoes and spices that have been developed using nanomaterials in India and exported to international territories. Hence, products are already penetrating international markets, quite unknown to many in the developed world. As these are still exported in very small quantities, any adverse impacts, from the sale of these products, would be most unlikely to be picked up, which would have major consequences of regulatory oversight. This further reiterates the importance of such regions to be included in international discussions on nanotechnologies.
However, both India and Canada have large land masses and are highly dependent on agriculture for economy growth. India has a higher arable land mass for food production, than Canada, a longer lasting growing season and warmer temperatures, which are more conducive to growing seasonal foods and fruits. This also means that India has greater losses in food that is produced, due to its climatic conditions. Such losses can be minimised through the effective use of new technologies like nanotechnologies, which will provide India the ability to transport fruits and store grain without spoilage for a long time. This also means that using such technologies could increase the income capita of farmers and provide food to the poor. Thus, in the pursuit of benefits for society and the country, India could develop nano-based products faster than the developed world. Hence, the inclusion of such developing countries in international debates and policy-making decisions will be essential to ensure that ‘responsibility’ in nanotechnology development is implemented. It is essential that government officials play a significant part in leading this approach towards RI instead of ignoring it so that when international regulations are eventually put in place, India would have given their voice and is able to trade in the global markets without hindrances. This is especially important because of the difference in the notions of ‘responsibility’ within this region.

8.2.6 Trans-Atlantic networks of collaborations

While the main aim of this study was to compare and contrast regulations and perceptions of ‘responsibility’ in Canada and India, the empirical analysis found various collaborations on nanotechnology-based projects in F&FP between Canada and India. This is significant and a major finding as it indicates that actors in two regions recognize mutual dependencies and engage in strategic interactions at a global level, which in future could create new markets of nano goods that meet international standards. The cases provide an example of transnational collaborations between actors based in regions that have different notions of ‘responsibility’, and where the relation to new technologies are seen to differ. These responsibilities are mapped through technical and scientific development capabilities. Through transnational collaborative networks, different ‘spatialities’ are able to tap into each other’s knowledge and skills in developing new solutions and products through symmetric notions of ‘responsibilities’ in an asymmetric landscape with differences in regulatory requirements.
In such collaborations the ‘responsibility’ for regulation of innovation, including conducting trials and monitoring project development, are seen to be distributed between two regions – India and Canada. Both parties conform to regulations within their region but work on negotiated and varied understandings of responsible innovation. We find that while there is no change in the innovation process, there is a change in the governance of innovation – a top down approach which involves government that enforce regulation within its jurisdiction, and beyond, on the one hand and on the other, a bottom up approach where the universities, and individual actors create frameworks of ‘responsibility’ that they adopt within the project. For example, in the mango FP project, innovative ideas are brought to market by a network of specialists based in two diverse regulatory settings. The dispersed innovation networks focus on core competencies and specialised activities of actors in these regions. Canada provides the technology for the chemical formulation (hexanal), while India works on the nano-film, thus building networks of distributed R&D globally. Roles are defined and allocated to various actors across the two settings based on their respective social, scientific and technological skills. Such collective co-operations, with shared willingness to engage constructively, have helped foster results-sharing between Canada and India, build capacity, reduce complexities and avoid duplication of efforts.

The project also outlines various conditions of governance that are set by the more dominant player, the funders based in Canada, where normative frameworks of ‘responsibility’ are embedded in their national regulations and governance regime (a combination of laws and directives). Sanctioning of funding for the project was based on a set of criteria that necessitated biosafety protocols and tests that were to be carried out in India. While such protocol-setting are mandatory to meet the regulatory requirements in Canada, tests have to be conducted within India and under Indian regulatory regimes. In such circumstances the regulatory protocols in India may not meet the requirements of high Canadian standards. However, the responsibility of these tests still lies with the Indian partners where the nano-film is developed and where the formulation is tested in mango groves. Given that these nano-films will in future enter Canadian markets, either through imports of mangoes or through the expansion of the technology to other fruits in Canada, they need to conform to testing standards that satisfy Canadian funders and regulators. However, in the absence of globally harmonized nanotechnologies standards/protocols for biosafety, an acceptable test regimen is implemented where high Canadian regulatory protocols are negotiated with the Indian counterparts and implemented
through collaborative dialogues. Such ‘negotiations’ not only influence Indian researchers to incorporate practices of ‘responsibility’ but also enables Canadian researchers to ensure that the resultant product from such collaborations meet the required standards needed to bring the product back to Canada for commercialisation in future.

Conditions of governance are also set through regular reporting and dialogues between the various actor groups on a bi-monthly basis, whereby a progress report is required to be submitted to the funders through the Canadian counterpart, who understands the regulatory requirements and protocols of Canadian authorities. We thus see an example of distributed ‘responsibility’ where actors across Canada and India work together and have a collective responsibility with respect to technological innovation. The process identifies the participation of a heterogeneous group of actors that are responsible for activities within their own jurisdiction. This demonstrates a comparative advantage for the two countries which has in turn leveraged the ‘responsible’ development of nanotechnology and the approach towards RI.

However, it is continuously being argued that developing countries are exploited by the West due to their weak regulations. Moreover, collaborations between developed and developing countries usually end up in a utilitarian and colonialist approach and are often seen not to be between equals. In the Canada-India mango project, a unique model of governance is seen, whereby Canada provides a good example of fostering international collaborations and enforcing high regulatory requirements in regions of low regulation through mutual agreements and negotiations with their partners in India (and Sri Lanka).

Moreover, by developing multinational networks and collaborations in these emerging markets, Canada is influencing the ‘responsilization’ of nano-products in these markets through a process where responsibilities are assigned to actors other than governments, and where they are involved in using a set of basic and commonly shared values and principles of governance and ethics. This aspect is reflective of the perspectives of proponents of RI who stress shared responsibility of actors in the ‘responsible’ innovation and development of nanotechnologies, and where no individual actor is identified as having the main responsibility of governing R&D in nanotechnologies. Such trans-Atlantic networks are expected to provide demonstrable benefits to both Canada and India and provide a base for future similar nano-based projects in F&FP, if successful.
8.3 Final comments

We have seen that there are various challenges when it comes to ‘safety’ regulation and governance of nanotechnologies. First, there is no universal agreement on the definition and size of nanotechnology. Second, if a company develops a nano-based product, there are no universally acceptable standards, laws or protocols currently to which manufacturers can refer to for guidance on such aspects as to the amount of the nanomaterial that is permissible in the product. Third, there is a lack of funding towards toxicology research in order to ensure the safety of a nano-based product. Fourth, consumers/CSOs want the freedom of choice through labelling of novel products, which risks not only the reputational image of corporations, especially large firms, but also the technological development/trajectory of new technologies, like nanotechnologies.

The cases of Canada and India sought to understand the current regulatory situation in asymmetric regulatory regimes and explore notions of ‘responsibility’/RI as is seen through the lens of different actors in the nanotech food chain.

Qualitative investigations revealed varied forms of ‘responsibility’ in nano-innovation in two dissimilar national regulatory settings. These included: (i) multi-stakeholder deliberative dialogues that involved not only scientific, institutional, and industrial communities, but also public representative groups, such as CSOs/NGOs; (ii) support by public/government institutions to promote domestic R&D, and therefore steer industry towards commercialisation and stimulate economic growth and development; (iii) the introduction of standards and policies that are developed through bilateral collaborative initiatives and international regulatory committees, to help establish new markets for nanotechnologies; (iv) putting trust on scientific knowledge and expertise, and reputable organisations for the ‘responsible’ development of nanotechnologies; (v) consumer choice where attitudes towards nanotechnologies are framed by celebrity advertising and positive media coverage; (vi) focus on grand challenges to develop solutions for the socio-economic needs of the society; (vii) promoting ‘responsible’ practices through transnational collaborative network projects between developed and developing nations.

While it was expected that there would be extremely diverse notions of ‘responsibility’, this study found evidence of both a common and differentiated approach towards RI between a
developed country and an emerging market. It also revealed that the globalisation of innovation of nanotechnologies has had significant implications for the Indian continent, bringing about subsequent international integration and shared responsibilities through transnational research networks. Thus, while this thesis initially intended to provide a comparative case study analysis of Canada and India, seeking to understand actors’ perspectives of ‘responsibility’ in F&FP in Canada and India, unexpectedly a fascinating example of a collaborative Canada-India transnational research network was seen.

The possibility that notions of responsibility are different across different spatiality cannot be ruled out. This research has shown that RI is accompanied by divergence and differentiation in the perceptions of ‘responsibility’. In India the focus is on the benefits of nanotechnologies rather than the risks. These notions of ‘responsibility’ for societal benefits, supplemented by notions of moral responsibility, that of providing solutions for the grand challenges of society, are driving government and firms alike to harness the potentials of nanotechnologies. In contrast, Canadian notions of ‘responsibility’ are built around increasing health benefits and strengthening food security. These specific results are important as they suggest that the regulatory structure and institutional settings adopted in these jurisdictions can be a significant influence on the practice and perceptions of ‘responsibility’ under uncertainty. Thus, these differences and divergent views bring new understandings that the governance mechanisms applied in developed countries may not produce the same uniformity as might be anticipated. This study therefore raises the importance of the regional context.

While the comparative nature of this research recognizes that there are wide differences in the regulatory structures and practices in these regions, there are many opportunities for good practices to be shared as well as indirectly ‘enforced’ (as through funding criteria) on weaker developing countries through negotiations and mutual understandings of what it means to be responsible. Further, there is a government drive behind R&D and funding of nanotechnology programmes for both countries as they see a potential for both societal and economic benefits. Although contentious, the implications are that the notions of ‘responsibility’ (to society) and (stringent) regulation affect these different geographies and create markets for nanotechnologies.
The interventions of intermediaries like NGOs and eminent personalities for the acceptability of nanotechnologies and subsequent use of nanofood and packaging products among farmers and consumers will be significant in establishing markets for F&FPN.

Thus, we have observed differences in regional response towards ‘responsibility’. Such differences can also be related to the regulatory settings of the two regions where we have seen that in Canada, stringent policies for novel food (as discussed in section 8.2.2) coupled with the scrutiny of NGOs (as discussed in 8.2.4.1) (and the media) have dissuaded manufacturing firms and retailers from incorporating nanomaterials in their products or disclosing use of nanomaterials. I argue that such surveillances from intermediaries and deterrents from the government creates a fear of public backlash and consequently self-restraint among firms.

Also, against prevailing concerns of risks, there is also an effort to limit any adverse repercussions of these nanotechnologies through self-regulation where biosafety tests are carried out on individual cases by firms, in nano-safety collaborations, or through (negotiated) enforcement by developed countries where project criteria are set by international funding agencies (as discussed in section 8.2.6). These prioritizations advocate crucial elements of RI philosophy.

Thus, such multi-disciplinary governance approaches in Canada and India are being used to enhance national competitiveness and strengthen food security.

Despite its low regulatory regime, India is likely to remain a destination for many developed countries, like Canada, due to its high technology expertise to research, develop and test markets for products of F&FPN through collaborative projects. As partners in mutually-beneficial collaborative projects, the intent of such developed nations would be to utilize India’s capabilities and low regulatory regime which could lead to successful outcomes in future. The formation of these international collaborations is likely to open up new markets for nanotechnologies in both these regions.

Thus, there are three main themes that have emerged from this study. (i) The perceptions of ‘responsibility’/RI are seen to be different, where the ‘responsible’ development of nanotechnologies are carried out based on perceptions of ‘moral responsibility’ and benefits for the poor, and providing healthy and safe food options, in India and Canada respectively;
(ii) Ideas of ‘responsibility’ in nanotechnologies are influenced through enforcement of certain criteria for R&D of nanotechnologies by the more dominant players in developed countries, thus signifying the return/intervention of State governance; and (iii) ‘Responsibility’ is exercised across transnational networks through symmetric notions of responsibilities in asymmetric landscapes.

8.4 Contributions, limitations and recommendations for further studies

8.4.1 Contribution to knowledge

8.4.1.1 Theoretical contributions

This study has contributed to knowledge by investigating the notions of ‘responsibility’ in two distinctly opposite and diverse regimes. Most of the studies on RI and governance of nanotechnologies focus on risk assessment and analysis, or consumer perceptions. This study provided an understanding of notions of ‘responsibility’ pertaining to nanotechnologies as was perceived by actors in the F&FP sectors, a sensitive area. The research revealed differing understandings of nano-responsibility by a heterogeneous group of actors based in a developed OECD country like Canada and developing/transitioning non-OECD country like India. It has thus contributed to filling a gap in the current literature on ‘responsible’ research and innovation of nanotechnologies by providing a developing country perspective and in addition a comparative assessment of perceptions of actors in two distinctly diverse regulatory regimes. Previous studies that covered perceptions of actors are largely focused to developed countries and such understandings of ‘responsibility’ pertaining to nanotechnologies from the lens of actors in a developing country like India are currently absent in literature. Thus, this study has contributed to literature by identifying the commonalities and key differences in the notions of ‘responsibility’/RI of emerging technologies in developed and developing/emerging countries. However, one should be cautious in generalizing the findings.

The study has shown that the notions of ‘responsibility’ pertaining to emerging technologies like nanotechnologies differ between a developed and developing country. This is unique in literature. While there is a vast amount of literature on the difference in CSR activities in different regimes and differences in regulations, this study is unique in that it examines the
ambiguous idea of ‘responsibility’ as seen through the lens of different actors in a new technology.

This study also contributes to the understanding of the unique role of intermediaries like NGOs and celebrities in the development trajectory of nanotechnologies, where they are used to promote benefits of nanotechnologies, educate public and appease potential backlash. This is novel to the literature on nanotechnology.

This study extends our knowledge of existing governance approaches of nanotechnologies in Canada and India. It provides an interesting insight into the growing interest of a low regulated country like India in leaning towards a North American or European model for ‘responsible’ research and development of nanotechnologies and the role of developed countries in influencing risk assessment studies and research on nanotechnologies.

8.4.1.2 Contribution to a framework for responsible innovation

This thesis also contributes to a framework for responsible innovation. The R³ Framework for Responsible Innovation (see Figure 9 in Chapter 3) brings together important elements (regulation-responsibility-region) that make significant contributions to the concept of responsible innovation. While reaffirming the importance of regulation and responsibility for emerging technologies the framework emphasises on region. The current frameworks of RI largely focus on the Global North with little attention given to the Global South, despite the risks of nanotechnology being widespread - across different boundaries and economic groups (Renn and Roco 2006, p.15). While it is argued by scholars that these frameworks have more general application (Stilgoe et al. 2013, p.1568), they fail to take into context various elements that are of greater relevance and needed for analysis in non-developed countries. The IRGC Risk Governance framework, while focusing on risk assessment and risk management, does briefly point to the issues of risk governance on a transboundary level and the need to include developing countries at an early stage of deliberation of nanotechnologies. However, it implicitly places governance of nanotechnologies in developing countries on the same level as developed countries without taking into perspective the structural, cultural and socio-economic constraints within these regions. I argue that the inclusion of region is an essential element for understanding perceptions of ‘responsibility’ of actors, and the differences in institutional structures are essential and necessary components of a RI framework. In order to explore how
these three elements are essential to the governance of emerging (nano)technologies I proposed an alternative framework – the R³ Framework for Responsible Innovation - to bring to the fore the issue of governance and aid in understanding the notions of ‘responsibility’ on a trans-boundary and trans-economic level.

Therefore, the R³ Framework for Responsible Innovation contributes to filling a gap in literature by providing a framework that can be used across different national contexts.

8.4.1.3 Empirical contributions

There are few empirical studies that investigate perceptions of various actors, specifically in the F&FP sectors. As an exception a study by Bakker et al (de Bakker et al. 2014) provides perceptions of actors in the nanofood industry in the Netherlands and a survey conducted by the Toray Research Center in Japan looked at manufacturers’ perceptions of nanotechnology use in the F&FP and food equipment industries and co-operative associations (FSCJ 2010). However, both these studies focused on actors in an OECD economy. There are some studies that have focused on the perceptions of scientists in a developing country like India (Patra et al. 2010; Sahoo 2013). However, these do not consider F&FP sectors and are limited in their focus on actors. The Nanoplant FP7 Science in Society project (CORDIS 2010) involved a deliberative process involving perceptions of a range of actors from within Europe using online chat focused on nano-based consumer goods but did not provide a detailed understanding of their perspectives. This study was conducted using qualitative interviews with a varied group of actors in the F&FP sectors in Canada and India to gain detailed information on the notions and understandings of ‘responsibility’/RI. These actor groups included government officials such as advisors, regulators and policy-makers, manufacturers/producers and retailers of food products, industry representatives, institutions and associations of F&FP products (including agri-food), university and industry scientists, lawyers, and local and international NGOs and consumer representative groups.

The presented study should prove to be particularly valuable to policy-makers, including standards agencies and regulatory authorities; commercial actors such as the food and retail sectors; scientists working on nanotechnology; the general public and other stakeholders that seek to understand the current position of developing/emerging markets like India in the
‘responsible’ development of nanotechnologies in F&FP. Other beneficiaries include NGOs and industry support agencies. The results are expected to:

- Lead to clear recommendations for current regulatory requirements for the F&FP and agricultural industries with a focus on understandings of ‘responsibility’ as viewed by actors in emerging and developed markets.

- Provide an understanding of the notions of ‘responsibility’ of different actors in the food chain and their role in the governance of nano-foods in OECD and non-OECD economies.

- Future best ‘responsible’ practices pertaining to the use of nanotechnologies in R&D and commercialisation of nanotechnologies.

- Help in the development of international regulatory frameworks for nanotechnologies in F&FP.

8.4.2 Areas for future research

Given that consumers are the end users of nano F&FP and agri-food products, their perspectives and notions of RI and who they consider is responsible were not taken into account due to the limited scope of this research. This can be a future research agenda. Various studies have been conducted to assess the concerns of consumers towards novel and emerging technologies and their safety in food. There have been many studies on the perceptions of people in developed countries for nano-products. This literature is lacking for emerging markets/developing countries, especially India. An idea of public understanding of nanotechnologies in India may shed further light on the implications of nano-products in this region and framings of nanotechnologies among the general population.

While this study took into perspective two regional settings with potentially disparate regulatory settings, a similar study with different regions/countries would be interesting to compare and contrast notions of ‘responsibility’ in order to investigate whether the unique notions of ‘responsibility’ are applied in other developed countries and developing/emerging markets.
This study discovered various areas in F&FP, including agriculture, where nanotechnologies were being applied. The environment implications of R&D of nanotechnologies were not taken into perspective. Unfortunately, data limitations prevented me from pursuing this issue and I acknowledge that this issue deserves further investigation.

8.4.3 Limitations

There have been many debates and controversies surrounding the use of nanotechnologies in F&FP, which brings to the fore many social, environmental and ethical issues. Under such circumstances some of the actors such as retailers and manufacturers in Canada that were approached for interviews were unwilling to participate in the study or disclose use of nanotechnologies in F&FP for fear of unwanted attention and public backlash. Thus, there is a gap in the data collected from F&FP companies directly involved in nanotechnologies in Canada. However, this limitation was covered through interviews with participants from food companies that had some exposure to the technology through their suppliers, or were directly involved in GMO, or had some interest and knowledge in nanotechnology, or were funding nano F&FP research at universities. Various researchers at universities that were aware of organisations’ activities or were collaborating with companies in R&D of nanotechnologies were also able to provide their perspectives and knowledge on the organisations’ roles.

As nanotechnology is an emerging area, it was very difficult to identify government officials, such as policy-makers, that would be ‘right’ for the interview and knew what was going on, as there are no specific departments for nanotechnology in Canada. Often officials that were contacted in S&T-related departments in Canada declined an interview on the grounds that they were not involved in nanotechnologies. Some of the government officials that were directly working on the nanotechnologies case file were fairly ‘new’ to the department and therefore were unwilling to give an interview as they were still studying the files. Establishing contact and getting confirmation for interviews with senior policy-makers was also difficult as they were unwilling to speak at the time or were genuinely too busy due to their demanding positions in their organisation (Marshall and Rossman 2010, p.156). Furthermore, during the time I was seeking interviews, the GoC was going through the restructuring of government agencies/departments and cuts were being made to the S&T budget by the new government regime. This may have resulted in biases in participant perceptions.
The constant delays in confirmation for interviews and absenteeism of participants resulted in considerable delays in collecting data from India. The time taken in India to collect data was twice the time taken to collect the data in Canada. Due to the delays and the constraints in the time required to complete this study, there is significant difference in interview numbers in Canada and India, whereby only 26 interviews were carried out in India as compared to 44 in Canada. However, it can be pointed out that each interview that was undertaken in India was twice as long (1.5 - 2.0 hours) when compared to Canada (45mins – 1 hour). Hence, this shortfall in interviews is compensated by the detailed amount of information gathered from each interview in India. However, there is also a variation in numbers within each actor group. While all attempts were made to include similar categories of participants in each region, the variation in numbers may have resulted in unintentional biases in the analysis. For example, differences in numbers in policy-makers from different departments.

One of the largest constraints while undertaking this research was the lack of technical/scientific knowledge in nanotechnologies. Various interviews with scientists generated very technical responses on issues of nanotechnologies, which required detailed study after the interviews. This may have resulted in the researcher being unable to ask deeper questions that might have been beneficial to the study.

8.4.4 Recommendations

8.4.4.1 Involving developing countries in global dialogues and EHS/ELSI R&D

From the research findings it can be established that the West is well aware of the research, development and commercialisation of nanotechnologies in emerging subcontinents like India, China and Africa. The potential of these emerging economies engaging in nanotechnology R&D is high as is indicated in the rapidly rising publications and patents within these countries (Palmberg et al. 2009). While, both China and South Africa are active participants in ISO processes and workshops and are involved in assessing toxicity of nanomaterials at the OECD-level, this study found that India has limited representation at the ISO and OECD level. Further effort needs to be made by India as well as the global community involved in the ISO and the OECD WPN to encourage greater participation by India in relevant international dialogues.
This is because the risks from nanotechnologies can have cross border implications and the repercussions from risks faced in one country may be due to failures in risk management in another country due to lax in regulations (Renn and Roco 2006, p.183). It is therefore essential that there is involvement of such emerging economies in international debates on nanotechnologies where there is regular export of food products to developed countries. This can be achieved through incentives and involvement of India in global dialogues and risk assessment projects as this study did show that India had the capacity as well as advance instruments to carry out these studies.

**8.4.4.2 Developing regulatory frameworks for nanofoods**

India has already developed F&FPN products which have been placed in the market as well as exported to developed countries, as found in this study. This is largely to gain a competitive advantage over competing nations (Renn and Roco 2006, p.183). However, there is a danger that that by placing these products in the markets, without carrying out sufficient evidence-based and internationally-approved tests, it may lead to detrimental and irreversible consequences across different continents. It is therefore crucial that an internationally agreed regulatory-framework on nanofood is put in place before conditions become urgent. A temporary regulatory framework for nanotechnologies is proposed as that similar to the one developed by the EU for nanofoods, which can be developed further as more information becomes available. As F&FP are more susceptible for penetration between borders, it should be a priority of the OECD WPN to develop a harmonised regulatory framework for governance of F&FPN until such time that new information is found and regulations are implemented.

It is also critical that international standards (as those set by ISO) and best practices are communicated globally to all stakeholders in a timely manner. An interviewee involved in standards-setting in Canada pointed out that many people, including NGOs, were unaware of the existing standards on nanotechnologies. This shows a lack of communication and distribution of information to actors. The distribution of information pertaining to new information on nanotechnologies is essential for propagation of RI. Though standards cannot be a substitute for regulation (ETUC 2010, p.13), it will help actors within developed and developing countries not only to understand the importance of consequences that may arise
from placing unregulated F&FP products in the market, but also provide some guidance to innovators using nanomaterials.

8.4.4.3 Regular deliberations on nanotechnologies in food and food packaging

More importance should also be given to F&FP in local and international deliberations on nanotechnologies. In both India and Canada, it was found that discussions on development of nanotechnologies in other sectors often overrides discussions on F&FP. As uncovered in this study, discussions on nanotechnologies in F&FP was triggered by this author’s request for interviews with policy-makers in Canada. It is essential that considering the various developments made on R&D of F&FPN, continuous relevant policy discussions and debates are carried out by regulators and policy-makers in order to keep up-to-speed with developments in R&D of F&FP and also to be able to develop/enhance regulations in a timely manner as progress is made. These regulators and policy-makers should also be open to discussions on issues pertaining to F&FPN and not shy away from providing information and their stance on issues pertaining to nanotechnologies as it is essential that they are seen as addressing these issues or at least looking into it.

8.4.4.4 Information sharing and reporting of EHS/ELS research

One of the challenges of risk governance is to ensure that appropriate risk assessment tools and methodologies are developed at the same pace as the applications (IRGC 2007, p.9). An effective approach to improving risk assessment and closing the existing knowledge gaps is to improve the quality of EHS research and create a comprehensive, publicly available database (Lewinski et al. 2009). Despite nano-cellulose being approved in Canada, this information was not updated on the DSL database of approved materials. It was only added to the database after the author in this study pointed it out to representations at EC. It is essential to record and update all directories of any approved nanomaterials so that the information is available to all stakeholders with regards to development of nanomaterials and its use in specific industries. Any approved use of nanomaterials in F&FP should also be communicated to all stakeholders through various media including through industry associations.

The nature of information asymmetries in the specific context of an emerging country and a developed country pertaining to EHS and ELSI also needs to be addressed through global
collaborations/partnerships and the sharing of risk research data and reports. As this study has shown, there has been limited effort by developed countries in sharing data on biosafety tests and have often ignored requests made by Indian researchers to share information. Thus, greater co-operation and exchange of risk information research is needed between actors on a trans-boundary level. There needs to be more effort by the Global North in working with these potential future markets in the Global South to share EHS-related information and therefore address the potential risks of nanotechnologies, which could lead to mutual benefits in R&D of nanotechnologies through cross-comparative analysis. For example, the approach taken by Canada in joint ventures with India (e.g. the mango nano-packaging project) and mutual/agreed understandings on their respective roles, which involves studying risks of nanotechnologies, could help both countries to leverage their respective skills and capabilities in the area, while also contributing to the knowledge of risk assessments of nanomaterials in F&FP. This knowledge should be shared with others in the field, not only for cross-analysis but also to ensure that India is not being used as a ‘guinea pig’ for carrying out unsafe tests.

There needs to be a strategy in place, perhaps at the ISO/OECD level, to create a comprehensive database, which can be regularly supplemented by contributions from the research community. This database should be publicly available to those seeking information on the safety of nanomaterials in F&FP. Access to this information will not only enable ‘responsibility’ in the way nanomaterials can be used (or not used) in F&FP but will also help speed up knowledge on the EHS of the technology, and lead to the timely development of standards and policies. This could also ensure the transparency and availability of risk assessment data, avoidance of major duplication of research efforts and promote maximal information sharing amongst the research community across continents.

8.4.4.5 Giving greater focus to risk assessment and risk management

In order to facilitate the ‘responsible’ uptake of nanotechnology, research focused on understanding the nanotoxicity of certain nanomaterials can help provide policy-makers the tools needed to develop and support regulations (European Commission 2015). In India, there is a lack of emphasis on nanotechnology where risk is concerned. This complacency in safety can lead to detrimental consequences. Therefore, dedication, focus and diligence are required by nano-innovators/entrepreneurs, scientists and regulators/policy-makers to address safety of
nanomaterials so that the potentials of nanotechnologies can be realised (European Commission 2015). It is important that the GoI address these issues alongside tests and interdisciplinary research and take a lead on it. With ongoing R&D in F&FP in India, a risk governance framework would also help in addressing the issues surrounding risks of nanotechnology and ensuring the ‘responsible’ development by scientists in India, while gaining maximum benefits.

The research on EHS can be carried out on a case-by-case basis. For example, many respondents in this study justified use of nanomaterials in F&FP products based on their notion that the materials are ‘natural’ or bio-based and hence safe. These suggestions of ‘natural’ nanomaterials being safe should be well-researched for nanotoxicity to ascertain and validate claims so that if true, these can be classified as safe, and if not, then its risks should be further investigated in order to avoid future catastrophes. Though, there are many discussions within literature where certain nanomaterials used in food is recognised as not being new as they have been in use for many decades (House of Lords 2010a) and differ from deliberate engineering of food on a nanoscale (Rogers-Brown et al. 2011, p.154), extreme caution needs to be made when claims of ‘naturalness’ are made by scientists working with nanomaterials in F&FP and clarified.

There should also be a clarity on the use of FDA’s GRAS status as a certification. Many scientists in Canada and India claimed that the nanomaterials were approved and given a GRAS status. However, these materials are only approved in a macro form and the nanoscale food ingredients do not meet the legal and scientific criteria in order for it to be regarded as GRAS. The use of such certifications to legitimise RI should be avoided and the government should work with industry to encourage consultation on new products incorporating nanoscale materials in F&FP.

8.4.4.6 Stronger industry focus on ‘responsible’ innovation

The study found that food companies in Canada were extremely afraid of linking their name to nanotechnologies due to fear of public opposition. This study, as well as previous studies, show that trust in industry and government is low when it comes to regulations of new technologies (Roco 2007; Rogers-Brown et al. 2011; Macoubrie 2005) due to past incidences specifically in the food domain, such as the BSE case in the UK and GM foods. It is therefore essential that
this trust is built up so that the benefits of nanotechnologies can be realised in future. This can be achieved by providing the public information on the various steps and procedures that are being used, including voluntary initiatives, to test nanofood and packaging products, to assess and mitigate potential health or ecological impacts, and the contingency plans that are in place to monitor and curtail any side effects of nanotechnology in future. Though engaging with the public and providing them with information may not be able to solve the problems of the ethical issues of nanotechnologies without providing factual evidence, it can help increase credibility and trust (Renn and Roco 2006, p.182) and may help allay concerns about inadequate regulatory oversight. Moreover, if food companies do not communicate how they are using nanotechnologies and what they know, these companies and their products are likely to be under scrutiny and growing concerns and distrust (Grobe et al. 2008, p.11).

Industry plays a key role in the diffusion of technology, due to their trans-boundary nature. It is therefore essential that they create, share and propagate best practices when it comes to R&D of nanotechnologies. In this study, it was found that various companies in Canada are conducting R&D of nanotechnologies in F&FP in collaboration with academia. In order to reduce risks and ensure safety, these projects should also simultaneously carry out rigorous safety assessment processes for nanomaterials that are science-based using advanced instruments and testing methods. A database of these assessed nanomaterials should also be created and a report with detailed characterization of the materials should be made available by the F&FP industry to various stakeholders, including academic and government scientists so that it can be properly assessed, replicated and matched with others’ findings. Where there is a ‘block’ in the assessments, it could be taken up by other entities, such as scientists in academia, to explore and recommend solutions. This will help create a database of ‘safe to use’ nanomaterials over time. While the collection of data from firms can be challenging and have IP issues, renewed cooperation between public-private organisations through incentives can accelerate the process and therefore encourage the ‘responsible’ development of nanotechnology.

### 8.4.4.7 Mandatory reporting

The existing information asymmetries between regulators and the regulated can contribute to inadequate regulation. Risk assessment is dependent on provision of adequate and reliable information to inform an assessment. In order to obtain information from industry, it is essential
for regulators to establish norms and incentive mechanisms to persuade the information from industry otherwise there is a danger that all the information on the safety of nanomaterials are not received. While there is criticism on the use of mandatory reporting, this may well be a way of collating data/information on nanomaterials. Since industry uptake of voluntary reporting schemes is low (Chaudhry et al. 2008, p.90) and has been largely unsuccessful (NNI 2013; Roco et al. 2010), a mandatory scheme will enable monitoring of nano-based R&D and F&FP products that are likely to enter markets. A registry would also make it easier to monitor and identify ‘responsibility’ for potential future risks and harm to human and ecological health (ETUC 2008), especially in the food domain that are continuously wreaked with catastrophes. It will also help in improvement of existing legislative frameworks for F&FPN.

The life-cycle assessment of the products should also be given due consideration, especially with products that are known and already in the market (e.g. nano-silver based filters, spices, agri-solutions in India). There should be strict monitoring of effects of all the products and contingency plans to contain potential negative effects should be put in place. REACH’s “no data, no market” should also be taken as a benchmark to restrict any products without adequate testing to enter markets. Strict application of this principle will oblige manufacturers to submit information that will fill the gaps in scientific knowledge about the safety of nanomaterials used in F&FP products.

### 8.4.4.8 Allocating sufficient funds

In order for the potential of nanotechnologies to be realised, it requires full attention to safety issues (Nel et al. 2006). This study has shown that there is an existing imbalance in the allocation of funds in both jurisdictions, where much of the funding is being diverted towards the R&D of nanotechnologies for commercial potential, and comparatively fewer resources are allocated towards EHS and ELSI aspects. In order to benefit from the potentials of nanotechnologies in F&FP, it is important to eliminate existing knowledge gaps that can hinder progress of the technology. It is therefore essential that a greater priority is given to the study of EHS/ELSA and nanotoxicity by allocating additional resources and time to enable study of nanomaterial and its product life-cycle. This means substantial financial support will be needed for nanotoxicology tests in order to meet the demands of nano-development (Maynard 2012, p.267). An EHS strategy with a commitment towards allocation of a certain percentage in
budget should be made by both the Indian and Canadian governments to enable consistent and focused responsibility on EHS/ELSI. These States should take proactive steps in initiating risk assessment tests for a number of nanomaterials currently being used in F&FP, including those with a natural origin.

8.4.4.9 Building regulatory capacity

This study found that there is a lack of knowledge and regulatory capacity within the government in Canada pertaining to nanotechnologies. The study highlighted that cuts in government budgets have further aggravated this problem. This lack of human resources could hinder the progress and development of regulations for nanotechnologies. It is essential, therefore, that adequate human as well as monetary resources are put in place to educate and facilitate better understanding of innovations in nanotechnologies among regulators and policy-makers.

8.4.4.10 Communicating the benefits and risks of nanofood and packaging

There is a need to reach out to consumers on the steps being made to assess safety of nanomaterials in order to enhance existing knowledge and education on nanotechnologies and thereby provide consumers more assurance on the food that they may be purchasing in future. If consumers have the reassurance that public authorities are taking measures to protect them against unintended risks of nanotechnologies, they may be willing to invest some more trust in the capacity of the authorities in regulating the technology (Renn and Roco 2006, p.182). This should involve (more) research into people’s perceptions of nanotechnologies in F&FP in Canada and India to fully understand the future of public responses to nanotechnology and whether or not they will be “the next GM” (Rogers-Brown et al. 2011, p.160). An investigation of the literature shows an absence of research in the perceptions of the public in India and few, old studies on the perceptions of the public in Canada. A regular study of the perceptions of the public in both regions will help understand the changing public perceptions/concerns of F&FPN, which could be incorporated into appropriate risk management and communication strategies (IRGC 2009, p.39). Further efforts can be made to educate the public at schools and university which can help provide an early understanding of the technology. Education (through various media, including social media) and engagement of the publics in deliberations
around the ethical and social issues of nanotechnologies, specifically in F&FP, will be key to promoting ‘responsibility’ in development of nanotechnology.

The engagement of CSOs/NGOs is essential, especially in Canada where they are essentially opposed to nanotechnologies. These entities must be continuously provided information on both the benefits and the potential health, environmental and safety aspects related to the use of nanomaterials. Though these entities may not entirely support innovations in nanotechnologies in F&FP, their inclusion in dialogues will in due course help build a “consensual approach” to regulation or self-regulation (IRGC 2009, p.31) The engagement of various actor groups in policy debates in Canada, and the implementation of a Nano Portal, which provides information on the opportunities and risks of nanotechnologies, are examples of ‘good’ governance strategies that should also be implemented in India. Additionally, in India, special focus should be given to poor, uneducated farmers on the risks involved in using nanomaterials so that they are aware of the potential negative repercussions of the technology and are guarded against unexpected consequences as well as scrupulous proponents that are looking for economic gains through the sale of products that have neither been approved or tested sufficiently. This would avoid a GM-type mishap when farmers committed suicide due to loss of income from crop failure and huge debts that they had incurred from purchasing GM seeds.

It is also essential to engage with celebrities and opinion leaders – both proponents as well as opponents of nanotechnologies - to ensure that they understand the risks and not only benefits of nanotechnologies. When deciding about controversial issues, consumers are often influenced by such opinion leaders, trusted leaders, or organizations that are well versed with science and technology. Keeping in mind that celebrities can also become activists (e.g. as it happened for GM foods), information-sharing would be crucial to ensure that these opinion leaders are not advocating wrong information. It is also important that those celebrities promoting nanotechnologies are cautious about over-hyping the technology and have done their due diligence in understanding the risks. Companies using celebrities to advocate nano-based products should be careful in misleading information as it can have detrimental issues in future for the technology.
8.4.4.11 Broadening of dialogue towards social and ethical issues in F&FP

The study found that there is a lack of deliberations on the social and ethical issues in India and debates at the regulatory level often focus on the economic benefits of nanotechnologies in various industries, including in F&FP than on the issues. There is also an attempt to avoid the “bad” NGOs in such policy debates where nanotechnologies are discussed. It is essential that the Indian policy-makers engage with various proponents and opponents of nanotechnologies in order to avoid future potential backlash and media criticism. An early engagement will help India curtail any unintended incidences as well as allow proponents to correct any misleading information and perceptions of nanotechnologies put forward by opponents of the technology.

8.4.4.12 Incorporating the lessons learnt from GM foods

One of the favoured analogy of nanotechnology is GM foods. This study pointed to various situations when the perspectives of ‘responsibility’ were linked to ‘what happened with GM foods’. The GM food analogy is not new (it can be seen in various previous literature from academic publications to government reports and opinion articles in the media) but has been seen to play a prominent role in motivating and framing the discourse on nanotechnologies. The reason behind this are the many similarities between the course that nanotechnology in F&FP and GM foods have taken – for example with respect to the novelty of the technologies, the uncertainties and knowledge gaps surrounding the technologies, divisive opinions on labelling, and the projected hype in terms of them being revolutionary as well as potentially being drastic. The similarities in the ethical and social contexts of nanotechnologies in F&FP and GM foods is important to consider especially as some of the CSOs/NGOs that have propagated and led opposition to GM foods are also apposing nanotechnologies. The scientific uncertainty resulting from innovations in nanotechnology is significant, and identifying lessons from past similar technologies like GM foods (such as application of the precautionary principle and engagement of stakeholders) will be valuable to enable ‘responsibility’ in technological innovation of nanotechnologies. A failure to incorporate these essential ‘lessons’ early on in the R&D of nanotechnologies can lead to difficulties in the economic trajectory of nanotechnologies and generate further ethical and social conflicts that could altogether stall innovations of nanotechnologies.
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APPENDIX 1: Interview questions

Thank you very much for taking the time out to speak with me. Before I begin, may I request permission to record the interview, solely for transcription purposes?

Just for the record, could you kindly introduce yourself and briefly describe your role in your organisation and your connection with nanotechnologies?

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<tr>
<th>QUESTION</th>
<th>PROMPTS</th>
<th>AIM OF QUESTION</th>
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| RESPONSIBILITY | As you are aware I am doing a PhD in the topic of Responsibility, Regulation and the Construction of Markets of Nanotechnologies in the F&FP industries in Canada and India. Firstly I am interested in learning how different actors and organisations understand responsible innovation and ‘responsibility’ pertaining to nanotechnologies. Can you describe for me what responsible innovation means to you, how it is understood from your perspective? | • What does responsible innovation mean in the Canadian/Indian context?  
• How is responsible innovation practiced?  
• Which are the institutes influencing responsible innovation (e.g. NGOs)?  
• What are the collaborations and discussions?  
• RI in emerging areas such as nanotechnologies has been the subject of intense discussions over recent month, how is Canada/India relating to ‘responsibility’ in nanotechnologies?  
• Is there any funding allocated to the ‘responsible’ development of nano?  
• How are notions of responsibility embedded in national regulations and governance regime?  
• Is there any labelling? Has it helped or hindered innovations in nanotechnology in Canada/India  
• What are the codes of conduct?  
• How much attention is being given to responsibility in nanotechnologies?  
• Is there funding allocated towards safety research and ‘responsible’ development of nanotechnologies? |
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<th>Question</th>
<th>Answer</th>
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| Considering the gaps in our scientific knowledge on nanomaterials with | • What are the main ethical and societal challenges of nano-enabled F&FP products in Canada/India?  
• How are the risks managed? How are the risks managed?  
• What are the appropriate risk management strategies in place?          |
| regards to health and safety issues, how is Canada/India dealing with  | • What are the ethical and societal challenges in nano F&FP?                                                                   |
| the ‘responsible’ development of nanotechnologies in consumer F&FP    |                                                                                                                                  |
| nano-products?                                                         |                                                                                                                                  |
| What specific applications of nanotechnologies in the F&FP and         | • What challenges do these bring to the governance of nano F&FP products?  
• What’s the R&D support provided by the Government?  
• What are the collaborations (company/university) local/international? |
| agri-foods are you working on?                                         | • To get an understanding of existing R&D in nanotechnologies.  
• How is it supported by the government?                                 |
| Who, according to you, are the main actors in the nanotech food chain? | • Who among them do you think is currently accountable for the safe and ‘responsible’ development of nanotechnologies?  
• Who (actor/actors in the food value chain) do you consider is responsible or should be made responsible for governing the use of nanotechnologies in the F&FP markets? Why?  
• How are they ‘responsible’?  
• Who do you think they hold responsible for undertaking this role/action currently?  
• Do you think that actors/other stakeholders in the value chain understand what ‘responsibility’ means pertaining to nanotechnologies? |
| What, according to you, should be the principles for responsible       | • Who do the actors in the value chain consider is responsible for governing the use of nanotechnologies in the food, and food  
innovation for these actors?                                             | packaging markets?  
• Who do different actors hold responsible for undertaking roles/actions for the responsible governance of nanotechnologies? |
<p>|                                                                        | • What the actors perceive are the principles of ‘responsibility’ that others should follow.                                    |</p>
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<tr>
<th><strong>REGULATION</strong></th>
<th><strong>What other regulatory instruments (be it regulation, participatory, labelling, etc.) have been brought in the governance of nano F&amp;FP? Which do you think have the most significant effect and why?</strong></th>
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<td><strong>Please describe Canada’s/India’s approach to nanotechnologies in F&amp;FP; are there any strategies?</strong></td>
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<td><strong>What steps has Canada/India taken in regulatory decisions - that in hindsight caused regulatory problems?</strong></td>
<td><strong>The US FDA recently issued new guidelines for companies for the safe use of nanoparticles. Is there any similar nanotechnology legislation in F&amp;FP in Canada/India which are in progress or have recently been proposed/ finalised/ made or likely to come up?</strong></td>
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<td><strong>Why?</strong></td>
<td><strong>What are the new challenges that you have faced/likely to face, if any, through this new legislation?</strong></td>
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<td><strong>How could this been done differently?</strong></td>
<td><strong>Can you provide any examples where the precautionary principle has been applied to F&amp;FP / agri-food products with nanomaterials?</strong></td>
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<td><strong>How might it be done differently in future?</strong></td>
<td><strong>What are the new issues and what new challenges do these bring to the governance of nano F&amp;FP products?</strong></td>
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[In 2009 Canada became the first country in the world to introduce a mandatory safety reporting scheme for companies producing nanomaterials. Since then, have there been any other important regulatory developments pertaining to nanotechnologies in Canada? To what extent has the labelling legislation helped with reviewing regulations in the country?]
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<th>Are you aware of any nano F&amp;FP products coming in from other countries to Canada/India (through purchases over the internet/directly)?</th>
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<td>How are they monitored and by whom?</td>
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<td>(According to the Nielsen report in 2008, over 80% of nano-products, including F&amp;FP nano products such as energy drinks, nutritional supplements, and food storage containers, produced in the US entered Canada through purchases made on the Internet or retail stores.)</td>
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<td>What role do you think NGOs in the nanotechnology value chain have?</td>
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<td>What about the public and other organisations?</td>
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<td>MARKET</td>
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<td>Could you please provide an overview of Canada’s/India’s international connections, collaborations and discussions on the governance of nano F&amp;FP in the global value chain?</td>
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<td>- Who, in your opinion, is responsible for assessing these products for toxicity – producer, manufacturer, retailer or/and Govt. bodies, or any other?</td>
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<td>- In case a product ‘goes wrong’, what are the precautionary or contingency plans that are in place? Has there been a case where this has happened in the past?</td>
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<td>- How are products monitored/governed through its porous borders? What are the processes in place to check entry/exit of nano F&amp;FP products?</td>
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<td>- How risks are perceived, how decisions are made and conflicts resolved, how risks are assessed, monitored and managed, who (which department/ regulatory body/ies are responsible, what are the appropriate risk management strategies in place, if any?</td>
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<td>- Who are the stakeholders (in the F&amp;FP value chain) that are involved in such discussions on policy-making on nanotechnologies per se?</td>
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<td>- The process and extent of participation of NGOs, public and other organisations which are able to initiate and influence public and government decision making (both formally and informally)</td>
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<tr>
<td>- How does the govt. involve other stakeholders in deliberations in decisions on the safe development, use and regulation? What are the mechanisms of engagement/ associations?</td>
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<td>- What are the existing collaborations, specific to nano F&amp;FP?</td>
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<td>- How are they governed internationally?</td>
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<tr>
<td>- In your opinion, how can the ‘responsible’ development of nanotechnologies in the F&amp;FP be ensured at the international level?</td>
</tr>
<tr>
<td>- What role is Canada/India playing in connecting with the global markets and territories in R&amp;D in nanotechnologies?</td>
</tr>
<tr>
<td>- At what stage of development is Canada/India in terms of commercialisation of nano-food and packaging products on a global platform?</td>
</tr>
<tr>
<td>- How, do you think, is responsible innovation understood by them?</td>
</tr>
<tr>
<td>- Who are the stakeholders (in the F&amp;FP value chain) that are involved in such discussions on policy-making on nanotechnologies per se?</td>
</tr>
<tr>
<td>- The process and extent of participation of NGOs, public and other organisations which are able to initiate and influence public and government decision making (both formally and informally)</td>
</tr>
<tr>
<td>- How does the govt. involve other stakeholders in deliberations in decisions on the safe development, use and regulation? What are the mechanisms of engagement/ associations?</td>
</tr>
<tr>
<td>REGION: INDIA/CANADA</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Do you foresee any significant changes in regulation coming into play over the next couple of years – either nationally or internationally?</td>
</tr>
<tr>
<td>How is Canada/India exchanging ideas to endeavour to avoid divergent emerging regulations on nanotechnologies – nationally and internationally?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What specific applications of nanotechnologies in the F&amp;FP are the transnational firms concentrating on?</th>
</tr>
</thead>
<tbody>
<tr>
<td>How is Canada/India exchanging ideas to endeavour to avoid divergent emerging regulations on nanotechnologies – nationally and internationally?</td>
</tr>
</tbody>
</table>

| I am interested in the licensing process. Can you talk me through the process - What’s the R&D support provided by the Government? Why support it? |
| What is the international process; Who is involved; How it came about? How is it accepted/turned down? |
| Illustrate with examples of nano-food and packaging products, or agricultural products, that are manufactured/produced/exported/imported through these processes? |
| (Inventors in Canada usually patent in both Canada and the USA, why is this so? |

| Illustrated with examples of nano-food and packaging products, or agricultural products, that are manufactured/produced/exported/imported through these processes? |
| How is Canada/India exchanging ideas to endeavour to avoid divergent emerging regulations on nanotechnologies – nationally and internationally? |

| Could you give me any examples of agreements and projects signed between India and Canada/India specific to nano F&FP R&D and products |
| What are the existing collaborations in R&D in nanotechnologies between these countries? |

| How are such companies monitored for responsible R&D in nanotechnologies in F&FP outside their jurisdictions? |
| How are MNCs/transnationals monitored for nanotech R&D when they set up their business in a region with low/limited regulation? |

| What is the support provided to F&FP transnational firms setting up business in such emerging markets? (Names of companies) What is the aim of this support? |
| How is Canada/India exchanging ideas to endeavour to avoid divergent emerging regulations on nanotechnologies – nationally and internationally? |

| Do you know of any collaborations between Canada and India on nanotech in F&FP? What can you tell me about them? What are they trying to achieve? |
| Could you give me any examples of agreements and projects signed between India and Canada/India specific to nano F&FP R&D and products |
| What are the existing collaborations in R&D in nanotechnologies between these countries? |

| Could you give me any examples of agreements and projects signed between India and Canada/India specific to nano F&FP R&D and products |
| What are the existing collaborations in R&D in nanotechnologies between these countries? |

| How are such companies monitored for responsible R&D in nanotechnologies in F&FP outside their jurisdictions? |
| How are MNCs/transnationals monitored for nanotech R&D when they set up their business in a region with low/limited regulation? |
| FUTURE |
|-----------------|-----------------|-----------------|
| How do you think the situation of responsibility will alter over the next five years? | - Where do you think they will move to? What’s Canada’s/India’s strategy?  
- Where would you like it to move to?  
- Where will responsibility move to?  
- Where will regulation move to?  
- Where will value chains incorporating nanotechnologies in F&FP and agri-foods move to?  
- Where will governing of value chains move to? | - How the respondent thinks the situation will change under each of the headings, single and combined, i.e. Responsibility, Regulation, value chains incorporating NFP Governing value chains, etc.  
- Is there a global demand for nano-based F&FP products?  
- Does Canada/India see a potential of a big global market for nano-foods and packaging in the near future in Canadian trade and commerce?  
- What are some of the future potential benefits of nanotechnologies for Canada/India in the F&FP industries?  
- Why is being involved with the global nanotechnologies community important to Canada/India? |
| And finally, is there anything else that you might want to add? | Seeking additional information that may not have covered in my interviews. |

Is there anyone that you could recommend in government (perhaps in different provinces) or industry that I should speak to, who might be able to provide me with further information and insights on this topic? May I use you as reference?

Just in case I need additional information in the near future, may I please contact you again? I am also likely to visit Canada in July/August and can meet them. I really do appreciate the opportunity of this interview. Once again thank you very much for taking the time to speak with me.
APPENDIX 2: ‘Non Nano’ packaging for a sunscreen product in Canada
APPENDIX 3: Celebrity branding for a cleaning product in India

Figure 13: Bollywood actor, Amitabh Bachchan, used on the packaging of cleaning products (Luxor Nano Clean) in India

Image source: Author
Figure 14: Luxor Nano Clean product "Specifically Formulated with Gold Nanoparticles" as specified on the packaging; and "Eco friendly" symbol on bottom right side

Image source: Author
APPENDIX 4: Nano-based agricultural products commercialised in India

Image source: Company website
APPENDIX 5: Nano-based water filters currently sold in markets in India

Figure 15: Nano-based TATA Swach water filter

*Image source: Web*

Figure 16: Aquasure water filter sold at less than £10, labelled as "Nano RO"

*Image source: Author*
APPENDIX 6: Water purifier incorporating nanomaterials installed in rural India

Figure 17: AMRIT water purifier developed and installed in a West Bengal district by IIT, Chennai’s spin-off company

Image source: Department of Science and Technology, Government of India Annual Report 2013-14
APPENDIX 7: Nanosilver food storage containers available on the Amazon website

Figure 18: Kinetic Go Green Premium food storage containers

*Image Source: Amazon website*\(^75\)

Figure 19: Kinetic Cookware Smarttwist Series

*Image Source: Amazon website*\(^76\)


\(^76\) [http://www.amazon.com/Kinetic-Cookware-Smarttwist-Rectangular-01002/dp/B0089AK8KU](http://www.amazon.com/Kinetic-Cookware-Smarttwist-Rectangular-01002/dp/B0089AK8KU), Accessed 1 April 2014
APPENDIX 8: Canada’s Eastgate Biotech Corp.’s nano-based nutraceutical product

Figure 20: Canada’s Eastgate Biotech Corp.’s nutraceutical product posted on Twitter

Source: Twitter post by the company

https://twitter.com/EastGateBiotech/status/559812079390306304/photo/1
APPENDIX 9: Term ‘Nano’ on yogurt products in Canada

Figure 21: 'Nano' on IOGO products advertisements in Canada

Image source: Author

Figure 22: IOGO product advertisement on the floors at the Toronto railway station

Image source: Author
APPENDIX 10: OECD Working Party’s list of manufactured nanomaterials (WPMN) for safety tests and countries leading tests

<table>
<thead>
<tr>
<th>NANOMATERIALS</th>
<th>LEAD SPONSORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fullerenes (C60)</td>
<td>U.S. &amp; Japan</td>
</tr>
<tr>
<td>• Single-walled carbon nanotubes (SWCNTs)</td>
<td></td>
</tr>
<tr>
<td>• Multi-walled carbon nanotubes (MWCNTs)</td>
<td></td>
</tr>
<tr>
<td>Silver nanoparticles</td>
<td>Republic of Korea &amp; U.S</td>
</tr>
<tr>
<td>Titanium dioxide (TiO$_2$)</td>
<td>France &amp; Germany</td>
</tr>
<tr>
<td>Cerium oxide (CeO$_2$)</td>
<td>UK/BIAC$^{77}$ &amp; U.S.</td>
</tr>
<tr>
<td>Zinc oxide (ZnO)</td>
<td>UK/BIAC</td>
</tr>
<tr>
<td>Silicon dioxide (SiO$_2$)</td>
<td>France &amp; European Commission</td>
</tr>
<tr>
<td>Dendrimers</td>
<td>Co-sponsors: U.S./Spain</td>
</tr>
<tr>
<td>Gold nanoparticles</td>
<td>South Africa</td>
</tr>
<tr>
<td>Iron nanoparticles</td>
<td>China &amp; BIAC</td>
</tr>
<tr>
<td>Nanoclays</td>
<td>BIAC</td>
</tr>
<tr>
<td>Aluminium oxide</td>
<td>BIAC</td>
</tr>
</tbody>
</table>

Table 9: OECD WPMN priority testing list of nanomaterials and countries leading the tests

Source: OECD Website$^{78}$

$^{77}$ BIAC is the Business and Industry Advisory Committee to the OECD

APPENDIX 11: Process of review by CIHR for responsible conduct of research in Canada

1. Researcher conducts research without Ethics Board approval

2. University conducts investigation

3. University finds breach of policy by researcher

4. University sends report to CIHR (with researcher name anonymised) within set timeframe

5. CIHR receives allegation on researcher

6. CIHR sends complaint to researcher’s University

7. University conducts investigation

8. University finds breach of policy by researcher

9. University sends report to CIHR (with researcher name anonymised) within set timeframe

10. CIHR panel on responsible conduct of research reviews report

11. Panel makes recommendation to CIHR President

12. CIHR Penalties: a letter of warning/ ban on funding for 1-2 years/ life ban on serious cases
APPENDIX 12: Nanotechnologies in Canada: further literature

R&D of nanotechnologies

In a recent S&T report by the Council of Canadian Academies, research in nanotechnologies was shown to be one of the fastest growing areas in Canada. British Columbia, Alberta, Ontario and Québec are the four main provinces that support and fund activities pertaining to nanotechnologies especially in the agriculture, F&FP areas. Public agencies, such as NanoQuébec, the National Institute for Nanotechnology (NIN) and NanoOntario, jointly funded by Universities and the Government of Canada, provide regulatory and policy advice to the Government of Canada and industry. These agencies actively promote, finance and foster collaborative projects in nanotechnology through various government-industry-academic programs, with an aim to establish the provincial regions as Centres of Excellence (CoE) in nanotechnologies locally and internationally. Millions of dollars (over $400m in Québec) of world-class infrastructures with state-of-the-art equipment have been set up in the provinces to cater to the research needs of scientists in academia and corporates alike. Funding is provided by the State and provincial governments for projects with a potential for economic growth. While the provinces have their own individual funding programs, they work extensively with the federal government, universities, corporations and industry groups to promote and support the R&D and commercialisation of nanotechnology innovations in the country, and stimulate investment in this emerging technology by businesses. Public-private partnerships are highly encouraged and supported. How nanotechnology is developed, commercialised and investments in nanotechnologies are made and conducted within its borders are thus set by the government. Various educational courses and funding are also offered to Canadians and immigrants interested in nanotechnologies within these regions.

Canada is the world’s largest producer of nano-cellulose. Canada became the first country to approve use of nano crystalline cellulose (NCC). In 2012, CelluForce became the world’s first producer of NCC, producing 1 ton of nanocellulose per day (ArboraNano 2012).

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Funding nano-based projects

In Canada, there are three major research grant agencies at the federal level – The Social Sciences and Humanities Research Council (SSHRC), The Natural Sciences and Engineering Research Council (NSERC) and the Canadian Institutes for Health Research (CIHR). The Natural Sciences and Engineering Research Council (NSERC) and the Canadian Institutes for Health Research (CIHR) are the two main agencies that fund research related to nanotechnology.

The National Research Council Canada (NRC), a government body is the primary national research and technology agency that also funds projects at universities. Through the NRC-IRAP (Industrial Research Assistance Program), the agency also provides financial assistance to small and medium-sized enterprises (SMEs) for innovation projects.

The Alberta Innovates-Technology Futures (Tech Futures) is an organisation that funds R&D work in nanofood and packaging primarily in Alberta and mainly with a focus on technology commercialisation. Non-governmental organisations, such as Canada Foundation for Innovation (CFI) are also instrumental in funding innovative projects and equipment.

Addressing EHS and ELSI

Canada acknowledges the need for a “balanced approach” for the ‘responsible’ development of nanotechnologies in terms of its benefits and risks and has developed various programmes to address the environment, health and safety (EHS) and ethical, legal and social issues (ELSI) of nanotechnologies. In 2006, the NE3LS Network in Québec was initiated in 2006 to deal with the Ethical, Environment, Economic, Legal and Social (NE3LS) aspects of nanotechnologies. The following year, both Health Canada and the Environment Canada, expressed the need to establish a regulatory framework “under the Canadian Environmental Protection Act, 1999 which enables the ‘responsible’ introduction of nanomaterials to Canada through the scientific assessment and appropriate management of the potential risks” (Environment Canada and

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80 Reporting to Parliament through the Ministry of Industry
Health Canada, 2007). In 2010, Bill C-494 was proposed in Canada to address this need. The Bill covers providing information on: (i) the use of nanomaterials and the need to add these to the Domestic Substances List (DSL), (ii) the physical and chemical components of nanomaterials, (iii) significant new methods used pertaining to the manufacture of the technology, (iv) the procedures used for risk assessment, toxicology data, and (v) establishing a public inventory of nanotechnology and nanomaterials in Canada. Establishing such programs that encourage focus on the ‘responsible’ development of nanotechnologies will in future help in the commercialisation of nano-products in domestic markets in Canada as well as exporting to international markets.

Compared to most other developed continents, including the EU/UK and the US, Canada appears to be quite focused to the responsible and safe development of nanotechnologies whereby its policy debates cover regulations to manage the EHS and ELSI aspects of the technology (Pelley and Saner, 2009). However, in a 2009 OECD WPN report, it was reported that Canada did not include ELS issues in its federal policy but was seen only in some provincial regions, like Québec. As early as in June 2006, the ethical issues and ‘responsible’ development of nanotechnology was raised by Québec’s Ethics of Science and Technology Commission (CEST) at a Nanoforum in Edmonton. CEST was created in 2001 and has been involved in issuing various statements on such issues as genetic databanks, GMOs and organ donation and transplantation.

Public perceptions

A research by Nielsen in 2008 found that Canadian consumers did not think that there was enough being done in terms of regulation of nanotechnologies by the government and they were also wary of the responsibility being given to organisations to self-regulate (Nielsen, 2008). The research also found that 70% of the Canadian consumers surveyed were unaware of nanotechnologies in products in the market. However, in spite of this, 58% of Canadians were optimistic about nanotechnologies and did not have any concerns about the use of nanomaterials in such areas as energy, medical devices, drugs and consumer products. Canadians associate nanotechnologies with biotechnology in terms of its risks and benefits

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82 In French – Commission de l’éthique de la science et de la technologie
(Pelley and Saner 2009; Roco et al. 2011) and thus showed concern when it came to using nanotechnologies in food, drugs and skin products (Nielsen, 2008). A majority of those surveyed did not trust the government and pointed out the need for a stricter regulatory stance that should be taken by the government to regulate nanotechnologies and address all social and ethical issues (Nielsen, 2008).

**Research collaborations**

There has been intense collaboration among inventors in Canada through local inter-cluster partnerships, as well as through international collaborations, and this has increased over the years (Schiffauerova and Beaudry, 2008). This has resulted in knowledge spillovers and repeat collaborations.

Federal science-based departments and agencies (SBDAs) are also involved in inter-departmental activities, such as regulation, public engagement, for the ‘responsible’ development of nanotechnology. The federal government agencies also collaborate with various external agencies like provincial nanotechnology associations, on issues relating to the ‘responsible’ development of nanotechnology (OECD WPN 2013).
APPENDIX 13: Nanotechnologies in India: further literature

Catching up on nanotechnologies

India has been slow in harnessing nanotechnology (TERI 2009b; Sharon 2013; Ramani et al. 2010) and is basically playing catch-up with other nations (Sastry et al. 2011; Ramani et al. 2010). Due to their slow pace in adopting nanotechnologies, India lacks the knowledge base, equipment and scientific and technological capabilities in nanotechnology, as compared to their developed counterparts (e.g. U.S.A, Japan, EU, Korea, Taiwan) that have invested sufficient time and huge amounts of money into this emerging technology at least 7-10 years earlier (Ramani et al. 2010; Sastry et al. 2011). While on the one hand this may sound to be a disadvantage for India, it has, on the other hand provided India the opportunity to ‘leap-frog’ its way past outdated technologies and equipment (Ramani et al. 2010b, p.2). Infact, in 2013-14, India ranked third in publications of scientific research in nanotechnologies (GoI Annual Report 2013).

Though the research, application and development of nanotechnology is still at a nascent stage in India, India is focusing on developing nanotechnology in specific sectors where it can provide greater impact to the social and economic development of the nation (for example the renewable energy sector, health, food and agricultural sectors, environment, personal care, electronics, automotive, construction, telecommunications, textile, manufacturing among others (Sharon 2013) p.8) and also get closer to reaching its MDGs by dealing with issues such as global warming and poverty issues, two of the major problems that India faces today (Sastry et al. 2011).

Industry associations promoting nanotechnologies

Three main public agencies, the Confederation of Indian Institute (CII), Associated Chambers of Commerce and Industry in India (ASSOCHAM) and the Federation of Indian Chambers of Commerce and Industry (FICCI) are actively involved in industry engagement and promotion of nanotechnology applications and commercialization in India at the national, regional and international levels (Sundararajan and Rao 2009; Beumer and Bhattacharya 2014; TERI 2009a). Non-governmental organisations like the Energy and Resources Institute (TERI) and
Global Innovation & Technology Alliance (GITA) are the other agencies involved in promotional activities.

These industry promoters have also been actively involved in opening up dialogues among the nanotechnology community in India and internationally through various conferences and programmes. The CII has already set up a Technology Development and Promotion Center (TDPC) in collaboration with the state government in Tamil Nadu (TN) (Ramani et al. 2010). (see Table 10 for agencies involved in promoting nanotechnologies)

<table>
<thead>
<tr>
<th>INDUSTRY ASSOCIATIONS INVOLVED IN PROMOTING NANOTECHNOLOGY</th>
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<tbody>
<tr>
<td>Confederation of Indian Industries (CII)</td>
</tr>
<tr>
<td>Federation of Indian Chambers of Commerce and Industry (FICCI)</td>
</tr>
<tr>
<td>Society for Automobile Manufacturers (SIAM)</td>
</tr>
<tr>
<td>Automotive Component Manufacturers Association (ACMA)</td>
</tr>
<tr>
<td>Associated Chambers of Commerce and Industry in India (ASSOCHAM)</td>
</tr>
</tbody>
</table>

Table 10: Industry associations involved in promoting nanotechnology

Funding nano-based projects

Though there is generous funding from government and venture capital for R&D projects in India (Bhat 2005), India lacks the funding it needs for R&D of nanotechnology, even though India does have the capabilities, both scientific and social, including adequate skills/resources, universities, English language skills and the technology know-how (Niosi & Reid, 2007). In comparison to investments by other governments, India’s investments in nanotechnologies are still small (Purushotham 2012). While its Western counterpart, the U.S.A., started with first-time investment in nanotechnologies of US$450 million in 2001 and China has been investing US$250 million per annum, India has invested barely US$22.8 million between 2002-2007.
(Michelson 2008). Moreover, the total estimated investment in India, as compared to other emerging markets like China and Russia, is still far behind (See Figure 23).

![Nanotechnology Funding by Country](source: Cientifica Ltd (2011))

**Figure 23: Nanotech funding by country**

Furthermore, public funds are mainly being directed towards scientific and technological capabilities. The projects that have been financed by the government have mainly focused on commercialization/application of nanotechnology. Seed funding has also been provide for courses at universities for students wanting to pursue M.Sc and M.Tech programs in nanotechnology (Ramani et al. 2010).

In 2001, the Nano Science and Technology Initiative (NSTI) was initiated by the Department of Science and Technology (DST). The NSTI’s main emphasis was to create Centers of Excellence (CoEs) in universities and nanotechnology R&D laboratories. Between October 2001-2006 the Department funded around 100 nanotechnology projects under this scheme.
Table 11: Centres of Excellence in India

(TERI 2009b; Sastry et al. 2011) by investing up to Rs. 60 crores\(^{83}\) and setting up nineteen CoEs across fourteen institutions that were earlier engaged in nanotechnology (See Table 11).

The main aim of these facilities was to develop nanotechnology scientific capabilities and nano-products. Much funding allocated to this initiative was also utilised to buy specialised equipment.

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\(^{83}\) Rs. 600 million
After the success of NSTI, a second phase, the Nano Science and Technology Mission (NSTM) was initiated, with a larger budget of US$ 250 million\(^8^4\), which was invested in projects between 2007-2012. This was distributed through the Nano Mission, which was established in 2007. Between 2013-14, further 24 projects were sanctioned by DST through Nano Mission\(^8^5\).

At the end of 2013-14, a further allocation of Rs. 650 crores, in a 12\(^{th}\) Plan Period, was approved by the GoI (GoI Annual Report 2013). These projects, some of which include research in F&FP, are funded for up to three years. (See Table 12 for further details on funding of projects by Nano Mission).

The objective of the Nano Mission, which is driven by the Nano Council, was not only to continue with high quality research but also to focus on nanotechnology application and development with active involvement and partnerships of research institutes with industries (Sastry et al. 2011; Ramani et al. 2010).

The Nano Council consists of not only government officials and scientists from the research institutes but also from industry, and is comprised of two advisory bodies – the Nanoscience Advisory Group (NSAG) and the Nano Applications and Technology Advisory Group (NATAG) (See Figure 24).

<table>
<thead>
<tr>
<th>TYPE OF PROJECTS</th>
<th>DURATION (IN YEARS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual/Group projects</td>
<td>3</td>
</tr>
<tr>
<td>Match-funded public-private projects</td>
<td>3-5</td>
</tr>
<tr>
<td>Projects to establish Centres of Excellence/research facilities*</td>
<td>5</td>
</tr>
<tr>
<td>Initiation of M.Sc./M.Tech. programmes in N&amp;N in public institutions*</td>
<td></td>
</tr>
</tbody>
</table>

*See Table 12 for further details on funding of projects by Nano Mission*

\(^8^4\) Rs. 1000 crores
Since 2009, the potentials of nanotechnology in agriculture has been explored through various R&D programmes funded by the government. ICAR is funding many projects on nanotechnologies in agriculture, the largest of which has been received by the Tamil Nadu Agricultural University (TNAU), India’s first State agricultural university to set up a Department of Nano Science and Technology\(^8\) (ICAR 2010).

Various other institutes of N&N have also been funded across India by GoI, including in Kolkata, Bengaluru and Mohali (Sundararajan and Rao 2009). State Governments in South India, Karnataka, Andhra Pradesh (AP) and TN), which over the years have established themselves as ICT hubs in India, are planning on building Nanotechnology Parks (TERI 2009a; Ramani et al. 2010).

DST has proposed to invest significant amounts of money to develop a Nano Park in Bengaluru, the Silicon Valley of India, which will be a base for companies to set up their office and research centres. Andhra Pradesh, the Asia Pacific headquarters of Microsoft, is also expected to build a Nanotechnology Park within the region. TN has proposed a nanotechnology park similar to the Hsinchhu Science Park in Taiwan (TERI 2009a). Kerala, on the other hand, has received funding from the GoI to set up a nanotechnology center. A National Institute of Nanotechnology in Agriculture has also been proposed by a Planning Commission under the National Agricultural Research System (TERI 2010a). (See Table 13 for details of DST funding for nanotechnology R&D for the period between 2001-2012)

<table>
<thead>
<tr>
<th>PHASE</th>
<th>PERIOD</th>
<th>INITIATIVE</th>
<th>FUNDING</th>
<th>INITIATIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>October 2001-2006</td>
<td>Nanoscience and Technology Initiative (NSTI)</td>
<td>Rs. 60 crores</td>
<td>Establishment of 19 CoEs across 14 institutions</td>
</tr>
</tbody>
</table>

\(^8\) An initial investment of Rs. 12 crores was allocated to TNAU to set up the department
Phase 2 2007-2012 Nanoscience and Technology Mission (NSTM)/Nano Mission Rs. 1000 crores Around 100 projects funded

**Table 13: DST funding for nanotechnology R&D from 2001-2012**

**Funding for risk assessments and EHS study**

The GoI appears to be working on a regulatory framework to address EHS issues, transparency and involvement of the public (Sharon 2013) though there has been limited progress so far. Funding for ascertaining risks in nanotechnology is quite low, compared to the availability of funds for nano-application and commercialisation (TERI 2009b). Venture capital is almost non-existent (Bhat 2005).

Some funding has also been allocated for research on toxicity of nanotechnologies. There are very limited number of institutes working on the toxicity of nanotechnologies (TERI 2007) and nanomaterials risk assessments are limited to few individual and ad-hoc studies (Sharon 2013) (p. 70). The toxicology tests are mainly undertaken by the Indian Institute of Toxicology Research (IITR), the Indian Institute if Chemical Technology (IICT), National Institute of Pharmaceutical Education and Research (NIPER) and the Indian Council of Medical Research (ICMR) (Sarma 2011; Ramani et al. 2010). Thus, though there are many research projects emerging on risks in various public institutes in India the GoI’s response to risk is slow (Sarma 2011). As regards transparency and ‘responsibility’, there is much gap between the enthusiasm of research scientists and the public who are wary of nanotechnology’s potential.

**Industry involvement**

It is not clear how many firms in India are involved in commercialization of nanotech products but biotech (nano devices drug delivery systems), chemicals and software companies are adopting nanotechnologies in their products.
Unlike its western counterparts—the U.S.A and the EU, industry involvement in India has been very slow. Larger players such as TATA Chemicals, Reliance Industries, Mahindra & Mahindra, Ashok Leyland, Asian Paints, Crompton Greaves have initiated R&D programmes in nanotechnologies within their organisations or in collaboration with local and international public institutes and academics (Purushotham 2012). The R&D investment in nanotechnology by these industries is substantially lower than the investment made by the Indian governments, unlike firms abroad that spend at least 2-3 times more than the Government expenditure (Sastry 2011).

However, there has been a drive by the government to promote collaboration between the public and private sectors. The New Millennium Indian Technology Leadership Initiative (NIMITLI), the largest PPP programme in India, is a publicly funded initiative by CSIR to encourage the industry in nanotechnology R&D. Hence recent developments have shown R&D efforts between universities and industry. For example, Delhi University collaborated with Dabur Research Foundation in India on a nanotechnology project. Banaras Hindu University developed a technique using nanotubes to produce a membrane out of carbon nanotubes for treating water that could be contaminated. Similarly, research at the Indian Institute of Technology (IIT), Chennai, developed a nanosilver-based water filter that can remove contaminants from drinking water. The technology was sold to Eureka Forbes (Sastry et al 2011). Nanosilver-based filters manufactured by Eureka Forbes are currently sold in the Indian market.

Other private companies that are involved in public-private partnerships include Smart and Innovative Textiles (SMITA) with the IIT - Delhi, Pluss Polymer Pvt. Ltd., Purolator India Ltd., and Resil Chemicals (Ramani et al. 2010b, p.6). New firms are also marketing nanomaterials and some of these are university spin-offs. For example, Monad Nanotech, which is a spin off by a professor from the IIT, Mumbai, and Innovations Unified Technologies, which is another spin-off by graduates of IIT, Mumbai (Ramani et al. 2010b, p.17). InnoNano Research Private Limited, a spin-off of IIT, Chennai, has developed and installed a water purifier, called AMRIT87 (Arsenic and Metal Removal Technology) incorporating nanomaterials in rural West Bengal (WB) (see Appendix 6 for image).
While many of the local firms are focusing on nanotechnology (Ramani et al. 2010), MNCs, such as GE and DuPont, have set up R&D Centers in Bangalore and Hyderabad, respectively, to research in the area of nanomaterials. All the companies using nanomaterials are operating as small scale companies. The International Advanced Research Centre for Power Metallurgy and New Materials (ARCI), in Hyderabad, AP, has filed an Indian patent for a nanosilver-coated ceramic candle for disinfection of drinking water. In collaboration with an NGO, the Byrraju Foundation, the nanosilver-based water filter has been installed in various village health centres in Hyderabad. The product, which is now being produced by SBP Aquatech Pvt Ltd., is currently on sale in the Indian market.

The Tata Group has also launched various water filters (see Appendix 5 for image) - an initial nanosilver-based Tata Swach water purifier and a more advanced version, Tata Crystalline, which was launched in August 2013. Other firms have also developed water filters using nanomaterials.

**International collaboration**

There have been several bilateral collaborations and S&T agreements that have been signed by India with other nations (such as the USA, the EU, Japan, Taiwan and Russia) involving nanotechnology R&D projects. India, Brazil and South Africa have also formed a “tri-lateral partnership” to work on programmes of their interest area that also incorporates nanotechnology. In order to encourage collaboration of scientists and technologists in India and those living abroad, a Scientists and Technologists of Indian Origin Abroad (STIO) association was formed. The CSIR has also been instrumental in setting up the International Science and Technology Directorate, which is involved in organising workshops. They work on several international projects in collaboration with South Africa, France, South Korea, China and Japan. To encourage collaboration between the EU and Indian scientists, the FP6 Euro-India Net, was initiated in 2002. A Memorandum of Understanding (MoU) has also been signed between India and UNESCO and a Regional Center for Education and Training in Biotechnology has been set up to work on nano-biotechnology. Various international conferences have also been funded by DST to promote Indian capabilities in nanotechnologies, including six between 2013-14.
## APPENDIX 14: Institutes funding EHS and ELSI research in Canada

<table>
<thead>
<tr>
<th>AGENCY</th>
<th>RESEARCH AREA</th>
</tr>
</thead>
</table>
| The Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) | • given funding to study the absorption mechanisms and the toxicokinetics of nanoparticles in the human body  
• research to ascertain the efficiency of gloves against penetration of nanoparticles  
• developed a best practices guide for handling of nanomaterials in laboratories and companies (most downloaded document on the IRSST website, used by other provinces, translated in Japanese for visitors) |
| NanoQuébec *(mainly funded by provincial government, partly by federal government)* | • funds projects on toxicology research; co-finances many projects with IRSST  
• launched call for technical projects on health and safety issues of nanotechnologies at universities; part-funding  
• active in organising workshops for industry to educate them about toxicity exposure of nanotechnologies  
• working on incorporating a funding criterion for additional research on toxicology or ethical issues of nanotechnologies in the near future. |
| Commission de l'Ethique de la Science et de la Technologie (CEST) | • research to explore the ethics of nanotechnology on nanofood |
| National Nanotechnology Institute, Alberta | • two individuals working on the EHS aspects of nanotechnology |
| Ministry of Agriculture, Québec | • study the implications of nanotechnology in food |
| NE³LS | • carries out independent research on safety issues of nanotechnologies. |
(Largely funded by provincial government – the Ministry of Higher Education and Innovation; also receives funding from NanoQuébec, IRSST and other organisations)

- part-financed a project on good practices guidance for safe handling of single walled nanotubes in industry; funded by ISSRT, and other institutes and companies
- funded short-term high risk pilot projects related to governance, ethics, and nanofood
- funded long-term projects, usually for up to two years, to study lifecycle of products from lab to industry to make a product “socially acceptable”

<table>
<thead>
<tr>
<th>Environment Canada</th>
<th>set up special division to study issues that may relate to the impact or influence of products from nanotechnologies on the environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Canada and Institute for Science and Policy</td>
<td>allocated funding to understanding the impact of nanotechnologies</td>
</tr>
<tr>
<td>Government of Québec</td>
<td>funding for eco-toxicology work to study the health impacts of nanotechnology</td>
</tr>
<tr>
<td>University of Calgary and University of Alberta</td>
<td>working on projects that involve ethical, legal and environmental issues</td>
</tr>
<tr>
<td>Carlton University</td>
<td>drafting their own guidelines for working with nanotechnologies on health and environment</td>
</tr>
</tbody>
</table>

**Table 14: Government, not-for-profit organisations and universities funding research on EHS & ELSI**
APPENDIX 15: R&D and products of nanofood and food packaging in Canada

R&D IN F&FP INCORPORATING NANOTECHNOLOGIES

This section provides information on the various nanofood and packing projects currently underway in Canada at various research institutes and universities. While the purpose of this thesis was to contrast notions of responsibility between Canada and India, interestingly, this study found cases of shared responsibilities through various on-going project collaborations with researchers in India, one of which has been investigated in this section.

Nano-based Projects in F&FP at Universities

According to a representative from a government funding agency, nanotechnologies are quite strong in pockets across Canada but because it requires a high degree of expertise and quite sophisticated laboratories equipment to do research, only a certain group of researchers and universities are focusing on it.

Projects at universities are either proposed by the organisation based on their need or initiated by scientists, which are then taken up by the firms. Smaller companies are using nano-based technologies to target the health and nutrition market. They are also targeting some of the bigger companies so that they can use their product as an ingredient in their larger products. Many of the companies in Canada are mainly owned by companies in the U.S., so a lot of the R&D also comes out of the U.S.

At the Alberta Innovates–Bio Solutions, University of Alberta and University of Guelph extensive attention is being given to research in applications in food (and health) and food packaging incorporating nanotechnologies. Various other research projects involving nano biosensors for food safety and intelligent fertilizers are underway at the Carleton University and Agriculture and Agrifood Canada, funded by the government. National farm associations are also supporting R&D in nanotechnology research in agriculture, one of whom is lobbying for financial assistance to support a project in smart fertilizers at AAFC. The Richardson Centre in Winnipeg Manitoba is working on innovation in canola oil. The George Morris Centre in Guelph, Ontario, is doing a lot of work on agri-food innovation. When it comes to agriculture and agri-food, the University of Guelph and McGill University in Montreal are actively involved in research in these areas.
According to participants, in Canada, ready-to-eat foods are very popular but there is a high risk of contamination of food due to bacteria, like listeria, e-coli or salmonella. Due to this, scientists are working on various projects that focus on food security and health benefits. Various projects are being carried out in nano F&FP and agri-food products. (See Table 15 for current research projects)

In packaging, research focused on three main areas - improvement of the barrier properties in packaging e.g. in meat packaging; better packaging e.g. products with antimicrobials that can prevent the growth of some pathogenic organisms and films for prolonging shelf life; and intelligent/active packaging e.g. delivery platforms (sensors) for the delivery of some nutrients e.g. a vitamin that can be released from the packaging into the food product to fortify (nutraceuticals) and colour change in food packaging when food is contaminated or exposed to high temperature. Patents currently exist for nano-packaging material involving gas barrier properties and packaging fruit products in Canada.
### Nanotechnology in Food

<table>
<thead>
<tr>
<th>UNIVERSITY/ORGANISATION/INSTITUTE</th>
<th>PUBLIC/PUBLIC ORGANISATION</th>
<th>RESEARCH AREA/S</th>
<th>FUNDING</th>
<th>COLLABORATION/S (INTERNAL/EXTERNAL)</th>
<th>COMMERCIAL USE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INRS</strong>&lt;sup&gt;88&lt;/sup&gt;</td>
<td>Public</td>
<td>Working on coating probiotic bacteria with nano beads</td>
<td>-</td>
<td>-</td>
<td>Probiotic bacteria when coated with nano beads, is resistant to gastric conditions and can be transported to the intestine without being destroyed. The nano beads can be taken orally or introduced inside meat, e.g. ham. Technology can also be used to kill bacteria in ham during the cooking process, using encapsulated nano beads.</td>
</tr>
<tr>
<td><strong>University of Guelph</strong></td>
<td>Public</td>
<td>Working on understanding bacteria and biofilms; Focusing on adhesion kinetics of bacteria;</td>
<td>Public</td>
<td>-</td>
<td>Can be attributed to yoghurt-based products to ascertain how probiotic bacterial activities can be enhanced within the gut.</td>
</tr>
</tbody>
</table>

<sup>88</sup> Research-oriented branch of the Université du Québec
<p>| Study of different bacteria behavior and movement (chemotaxis); attachment and communication among bacteria (quorum sensing). | Developing smart surfaces for food industries to repel and prevent bacterial-related infection and diseases | Collaboration with a company that manufactures flour, cereal grains, pasta for companies like Kellogg | Expected to be used in chutes, elevators, belt conveyors, cutting tables, which are made up of stainless steel and aluminium, and different conduits that come in contact with food in huge manufacturing facilities; also the milk industry during sterilization of milk. Received many interests from major manufacturers of different equipment for restaurants and food manufacturing industries. A similar project on smart surfaces, focused more on biomedical, is being carried out in... |</p>
<table>
<thead>
<tr>
<th>Developed a methodology to extract and synthesize nanomaterials and nanoparticles from “green products” or “bio products” (considered safer to use than chemical-based sources of nanoparticles)</th>
<th>Public</th>
<th>-</th>
<th>To be used as a coating for drug delivery system, nutraceuticals and supplementary health products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineered nano crystals from fat Using a structured emulsion scientists have created Coasun, - trans-fat-free and low in saturated fat, which helps reduce fat in food by up to 40%</td>
<td>Much of the funding for these projects provided by NSERC &amp; Canadian Foundation for Innovation, and through the CRC program</td>
<td>Allows certain mechanical properties in fats to be changed e.g. fat can be harder, softer, have more plasticity and have different functionality like laminating fats or shortenings</td>
<td>Coasun - used as shortening alternative in confections and bakery no taste or smell; increases shelf life of products such as cookies;</td>
</tr>
<tr>
<td>Company</td>
<td>Public</td>
<td>Nanoparticles</td>
<td>Encapsulation of food bioactive components e.g. omega-3 fatty acids oil is encapsulated into very tiny nanoparticles</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------</td>
<td>---------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>University of Alberta</td>
<td>Public</td>
<td>More than CAN$4m</td>
<td>Working primarily around food texture and nano emulsions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Public</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Encapsulation of food bioactive components e.g. omega-3 fatty acids oil is encapsulated into very tiny nanoparticles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The hard gel created from liquid gel can have many functionalities, including in heat resistant chocolates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>a large multinational already introduced a product in India using this technology for resistant chocolate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Created solid-like materials called <em>oil gels</em> or <em>oleogels</em> by incorporating specific polymers in oil using nanoscale structuring</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>has functionality of a solid fat in liquid oil; patented in Canada, U.S., EU, Singapore, and Brazil, though it took 8yrs to get patent</td>
</tr>
<tr>
<td>University of Toronto</td>
<td>Project involves nanoencapsulation of barley, where barley is separated into base levels of proteins, lipids and starches</td>
<td>Both projects funded by NSERC; sponsored by companies</td>
<td>Working with companies</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td>Lipid-based nanotechnology (10nm) for the delivery of active ingredients in food; extracted lecithin from soya beans using a process called degumming process</td>
<td>Extract oils and nutrients from biomass</td>
<td>Can be added to pasta or cereals - reduce lycopene costs extracted from tomato peels</td>
</tr>
<tr>
<td>University of Waterloo</td>
<td>Public</td>
<td>Developed a water disinfectant system based</td>
<td></td>
</tr>
<tr>
<td>FOOD PACKAGING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>University of Toronto</strong></td>
<td>Public</td>
<td>Nano-packaging</td>
<td>Private</td>
</tr>
<tr>
<td><strong>INRS</strong></td>
<td>Public</td>
<td>Working on active packaging using nano polymers to develop biodegradable film, edible coating or encapsulation of food</td>
<td>Public</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Working on biodegradable film for food packaging by introducing nanocellulose into chitosan(^{89}), in presence of an antimicrobial compound</td>
<td>For 5yrs</td>
</tr>
</tbody>
</table>

\(^{89}\) an insoluble polysaccharide extracted from shrimp or lobster shells  
\(^{90}\) a Canadian not-for-profit research center with focus on forest research
the film and also control release ofcompound
Currently being evaluated for itsantimicrobial properties inpackaged ham
Formulation of the technology,with the antimicrobial compound,and without nanocellulose beingused by industry as edible coating;tasteless and transparent, and usedas a spray over food

<table>
<thead>
<tr>
<th>Company</th>
<th>Type</th>
<th>Technology</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platemeat</td>
<td>Private</td>
<td>Nanotechnology coatings</td>
<td>-</td>
</tr>
<tr>
<td>Carleton University</td>
<td>Public</td>
<td>Biosensors for food packaging</td>
<td>-</td>
</tr>
<tr>
<td>University of Guelph</td>
<td>Private</td>
<td>Utilizing electro spinning technology to spin polymer into fibres (smaller than 100 nm) to be used in F&amp;FP</td>
<td>-</td>
</tr>
<tr>
<td>Nanotechnology for diagnostics: involves coating nano beads which are magnetic, with a polymer that has imprints towards viruses</td>
<td>Working with the Homeland Defence in the U.S.</td>
<td>Used to capture and detect viruses</td>
<td></td>
</tr>
<tr>
<td>Nanotechnology for diagnostics: involves electro spun fibres, or nano fibres, which are loaded with antibodies</td>
<td>-</td>
<td>-</td>
<td>Used for the detection of pathogens</td>
</tr>
<tr>
<td>Working on release of anti-microbials in packaging using natural AITC(^{91}) present in mustard oil</td>
<td>-</td>
<td>-</td>
<td>Has anti-bacterial property</td>
</tr>
</tbody>
</table>

**Alberta Innovates – Bio Solutions**

| Nano-sensors for food packaging | Public | - | To detect the presence of a bacteria in food |

\(^{91}\) Antimicrobial Compound Allyl Isothiocyanate (AITC)
<table>
<thead>
<tr>
<th>University of Alberta</th>
<th>Combined material chemistry and genomics to create a technology for packaging that reads the DNA of any bacteria and then reports it as a colour change</th>
<th>-</th>
<th>Several industrial partners</th>
<th>e.g. Logo on the package changes colour if product is contaminated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGRICULTURE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Guelph</td>
<td>Public</td>
<td>Nano-sensor - developing a quality monitoring system for food storage</td>
<td>Mainly NSERC: others include OMAFRA, Ministry of Environment, AAFC, CFI, CIHR, CMC, Home Credit Canada and Grain Farmers of Ontario</td>
<td>Various companies</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Developing disease and drought resistant crops by understanding the molecular genetic make-up of particular species. Using nano-based imaging tools and imaging techniques to understand the DNA in chromosomes and the genetic linkage between DNA and different diseases.

To avoid diseases like the bacterial blight in quinoa, buckwheat and beans. Involves synthesizing nano crystals, nanoparticles and nano colloids from plant-based materials for different nutraceutical health supplements.

| Alberta Innovates – Bio Solutions | Public | Investigated the efficient uptake of nitrogen fertilizer\(^\text{92}\) | Public for 5 years | - | Other organic compounds by wheat and canola, found in the soil check. |
| Agriculture and Agri Food Canada | Public | Various projects, including one on retention of fertilizers in soil | Public | - | Fertilizers can be retained from being washed away in the soil. |

\(^\text{92} \)70% of the nitrogen fertilizer is normally lost in the soil.
‘Smart fertilizers’- involves codings (biodegradable polymers) that are contained within a receptor on the fertilizers

Carleton University

Involves receptors that are able to respond to a crop’s nutrient needs such as nitrogen or phosphorous

Technology expected to help farmers cut their expenses by curtailing use and wastage of fertilizers, and thus decreasing environmental and economic problems

Also expected to be used for herbicides and pesticides

| Carleton University | Public | Using the same technology as above | - | Collaborating with Europe | Currently used in fields to detect food-related toxins like micro-toxins, which are moulds that can occur on crops or during grain storage. |

**Table 15: Summary of major R&D and application in nanofood and food packaging in Canada**
APPENDIX 16: Process for introducing a nano-packaging product in India

In the current system, if a company wanted to place a nano-packaging product in the market, as with all novel packaging materials, the company will have to approach the Food Safety and Standard Authority of India (FSSAI), who are responsible for regulations on packaging, and provide all the necessary documentation and assessment results for approval of the product. However, if the nano-based product or material is sold to a third party or company, for example, if it is sold to a water purifying manufacturer, then that company would have to then apply for approvals and provide the documentation to FSSAI. Even if products are developed at universities and the IP is licensed to a commercial entity, then the entity which is commercialising it has to take the responsibility and get the necessary clearances from the government, by getting the novel material tested for safety using a government-approved testing lab.
### APPENDIX 17: R&D and products of nanofood and food packaging in India

<table>
<thead>
<tr>
<th>UNIVERSITY/ ORGANISATION/ INSTITUTE</th>
<th>PUBLIC/ PRIVATE ORGANISATION</th>
<th>RESEARCH AREA/S</th>
<th>FUNDING</th>
<th>COLLABORATION/S (INTERNAL / EXTERNAL)</th>
<th>COMMERCIAL USE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NANOFOOD &amp; FOOD PACKAGING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| TNAU                               | Public                      | • *Nano Agri-food:* nano fertilizers, nano herbicide, nano insecticide and nano seed science  
• *Nano Food Systems:* nano encapsulation of functional foods and nano-packaging material  
• Nano Biotechnology  
• Nano Remediation and Biosafety | Rs. 700,00,000 ($2 million) from ICAR; likely to receive an additional investment of at least $200m in the next five years | University of Guelph (nano-film) | Nano-film used in packaging of mangoes |
| DFRI-DRDO                          | Public                      | Nano-packaging to prolong the freshness and shelf-life of food | Government | DRDO - FICCI ATAC programme | Currently used in:  
• packaging of spices of leading companies - MTR and MDH;  
• processed food companies (e.g. Knorr); |
| IIT, New Delhi | Public | Polymer nano composites for packaging materials in the form of sheet or films – to extend shelf life of food:  
- developed polymeric film with anti-microbial properties to extend shelf-life of food  
- developed fillers with different barrier properties and strength; controls permeability of gases such as moisture and oxygen | Government | Developed a film for packaging of cereal nutri-bars in collaboration with an institute under the IIT umbrella  
Expected use: E.g. when packaged coconut water is opened in a warm climate, it will turn cold. Similarly, various ready-to-eat processed food items, when opened, will warm up  
- Received huge interest from major polymer producing industry for nano filler based packaging for developing anti-microbial films for packaging |
| **ORG1, Mumbai** | **Private** | **Anti-bacterial product incorporating nanosilver particles; available in the form of a liquid or powder** | **The nanosilver product is directly added to plastic, which is:**<br>• used to manufacture bottles and caps for drinks<br>• used in water purifier compartments which come in contact with water<br>• also expected to be used in plastic boxes used in packing of take-aways |
### ORG2

**Private**  
**Biosensors**  
**Personal**  
**-**  
**To detect pathogens in food**

- Developed a nano composite packaging material using nanomaterials and a biomaterial  
- Has thermal barrier properties for storage  
- Also has anti-microbial properties to enhance shelf life of food and drinks  
  
A food and packaging polymer industries association  
Expected to be used in packaging beverages, wine and beer in polymer bottles, rather than glass bottles; to launch in Europe and Africa using distributors

---

93 A joint venture between the Shapoorji Pallonji Group’s Aushim Gupta & Company Ltd., India, and Electrolux, Sweden
| NDRI | Public | • Working on development of milk (whey) protein-based films incorporating very fine cellulose-based nanoparticles  
• Involves a safety component involving 6 scientists, to test the validation of these nanomaterials;  
• Developed detection kits using gold nanoparticles, for detection of adulteration and contaminants in milk;  
• Assigned projects in the areas of delivery systems and packaging | Government; budget of Rs. 200 crores focusing on nanofood, involving twelve different institutions across five zones in India | Various institutes across India; lead researchers Central Potato Research Institute | Edible and non-edible nano composite material for primary and secondary packaging material |
|-------|--------|---------------------------------------------------------------------------------|-------------------------------------------------|-----------------------------------------------------------------|---------------------------------------------------------------|
| CIRCOT | Public | • Developed nanocellulose-based nanocomposites and fillers for packaging to | World Bank; Rs. 4.5 crores for 4 years. | Nanocellulose-based composites developed at CIRCOT, while the | • Currently under a pilot stage  
• Packaging of fruits;  
Nanocellulose\(^{94}\) is added as |

\(^{94}\) As a by-product of cotton fibre, nanocellulose increases strength and reduces the permeability of water vapour and oxygen, thus increasing the shelf life of fruits
<table>
<thead>
<tr>
<th><strong>Luxor Nanotech</strong></th>
<th>Private</th>
<th>Nano-based anti-corrosion products</th>
<th>Private</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CSIR</strong></td>
<td>Public</td>
<td>Developed a terracotta-based water filter candle incorporating silver nanoparticles</td>
<td>Government</td>
<td>Set up commercial scale units in rural areas with State Governments; later an organisation took up manufacturing of</td>
<td>-</td>
</tr>
<tr>
<td><strong>NANOTECHNOLOGIES FOR WATER PURIFICATION</strong></td>
<td><strong>CSIR</strong></td>
<td><strong>Public</strong></td>
<td><strong>Developed a terracotta-based water filter candle incorporating silver nanoparticles</strong></td>
<td><strong>Government</strong></td>
<td><strong>Set up commercial scale units in rural areas with State Governments; later an organisation took up manufacturing of</strong></td>
</tr>
<tr>
<td><strong>NANOTECHNOLOGIES FOR WATER PURIFICATION</strong></td>
<td><strong>CSIR</strong></td>
<td><strong>Public</strong></td>
<td><strong>Developed a terracotta-based water filter candle incorporating silver nanoparticles</strong></td>
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</tr>
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<td><strong>Luxor Nanotech</strong></td>
<td>Private</td>
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<td>Private</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Luxor Nanotech</strong></td>
<td>Private</td>
<td>Nano-based anti-corrosion products</td>
<td>Private</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Increase the shelf life of fruits
  - Part of the National Agricultural Innovative Project

- Starch film developed at the Institute of Chemical Technology, Mumbai; microbial toxicity and cell toxicity tests conducted at the IITR in Lucknow

- An additive in starch films, which can be wrapped around fruit
  - Researchers working with companies that own orchards and will take it to market
  - Received interest from organisations in Sweden and France

- Anti-corrosion products tested on metal that come in contact with food
  - Also tried as a coating on apples to increase its shelf-life
  - Also tested on bread (in the lab) where the material was found to have anti-fungal benefits for up to four weeks

- Used to provide clean drinking water for villagers
  - Filters can be easily manufactured by semi-skilled
<table>
<thead>
<tr>
<th>Institution</th>
<th>Type</th>
<th>Technology Provided</th>
<th>Funding Sources</th>
<th>Area of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIT Chennai</td>
<td>Public</td>
<td>Silver coated nano membrane for the water filter</td>
<td>Government</td>
<td>An Indian conglomerate provides bacteria-free drinking water to villagers without the use of electricity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>People in rural settings, thus saving them costs</td>
</tr>
<tr>
<td>IIT Mumbai</td>
<td>Public</td>
<td>• Sensors based on electrochemicals for testing drinking water</td>
<td>Government &amp; Private:</td>
<td>The sensors are dipped in water to detect for contaminations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Few millimetres in size</td>
<td>• DST through the Techno Entrepreneurs Promotion Program</td>
<td>Already commercialised (same concept is used to develop a system for testing soil for nitrogen, potassium and phosphorus in agriculture)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Made using screen printing</td>
<td>• Major portion of research funded by Media Lab Asia, an agency under Department of Information Technology that support innovative projects</td>
<td></td>
</tr>
</tbody>
</table>
Also funded by a not-for-profit organisation, Rural Innovation Network (now called Villgrow)\textsuperscript{95}

Funding from Ashoka Foundation towards marketing costs

### NANOTECHNOLOGIES IN FISHERIES

| CIFT          | Public | Chitosan\textsuperscript{96}-based nanocomposite films, water soluble chitosan nano derivatives with antimicrobial properties | Government | - | Also submitted two proposals in harvest and post-harvest technology |

\textsuperscript{95} An international donor agency  
\textsuperscript{96} Second most plentiful natural biopolymer and is relatively cheap (Dutta et al 2004); has antimicrobial property
<table>
<thead>
<tr>
<th>CSIR-CFTRI - The Fermentation Technology &amp; Bioengineering Department</th>
<th>• to determine the presence of toxins in marine food using nanotechnologies</th>
<th>Spanish company</th>
<th>Also expected to collaborate with a local nanotechnology instrument development company in Bangalore to develop molecular diagnostic methods using nanotechnologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORG4</td>
<td>Private</td>
<td>Personal</td>
<td>-</td>
</tr>
<tr>
<td>• Duplicated a nano-silica based compound developed by DuPont in the late 1950s and loaded it with micro-nutrients that could easily be absorbed by diatoms</td>
<td>• Product containing nano silica has developed to stimulate growth of diatoms in water bodies in fish farming</td>
<td>• Product approved for import by the Environment Protection Agency in the U.S.A.; currently used by Lake Savers and Clean Flow to clean up lakes and ponds in the U.S.; approval from the Michigan Government approval awaited to use the product to clean up the Great Lakes;</td>
<td>• Exported to South American</td>
</tr>
</tbody>
</table>
• Product modified for crop agriculture, by including silica-based nanoparticles (5-10 nm in size) containing micro-nutrients essential for plant photosynthesis
• Product available in a suspension liquid form – 30 grams per litre;

Government funding of Rs. 2,00,000 towards field testing; personal funding of Rs. 100,00,000

• Used in crop agriculture in Hassan, South India; sprayed on the leaves of plants
• Increased yield in crops – such as corn (from 1.5 tonnes/acre to 3 to 3.5 tonnes/acre) and sunflower (doubled);
• Enhanced flavour of mangoes, sapota, and jackfruit
• Biannual crops increased yield every year
• Extended shelf-life of tomatoes
• Product due to be given a safety certification by Karnataka State Sericulture Research and Development Institute
• Patents in India, USA, UK, Germany and South Africa

NANOTECHNOLOGIES IN AGRICULTURE

ORG3          Private

• Various nano-based solutions for use in Personal -

• A suite of products for plant and animal supplement
| **agriculture, tea plantations and dairy farms (10 to -17 nm)** | • Extracted from plants | **• Solution used in mango orchards and vineyards; sprayed on leaves of mango trees to enhance taste, without increasing sugar levels**
• Fruits exported to UK and Japan
• Minerals, such as calcium and potassium present in the product, absorbed by plant depending on their specific needs
• Raw materials provided to Willmar Shwabe\(^\text{97}\)
• Used by Williamson Magor\(^\text{98}\) – increased production of tea (from 1 ton/month to 3 tons/month)
• Product received IndoCert\(^\text{99}\) certification in 2010 |

\(^{97}\) A German homeopathic organisation
\(^{98}\) An English company with 20% of its tea production in India
\(^{99}\) A GoI certifying authority for organic farming
| ORG2    | Private | • Developed nano pesticide that can kill microbes, such as bacteria or fungus in plants  
|         |         | • Also conducting nanotoxicity tests on its products | Personal | - | • Applied to Tea Research Association in Northeast India for ‘organic’ certification  
|         |         | | | | • Completed field trials  
|         |         | • In the process of licensing and patenting the product  
|         |         | • Received interest from farmers in Russia and Africa |

| NANOTECHNOLOGIES IN POULTRY AND FARMING |

| ORG3    | Private | Product used in dairy farms to help increase milk, fat, and SNF (Solid Not Fat) yield | Personal | - | • 30 ml of solution is added to 1 litre of water and given to animals along with their feed as a supplement once a day  
|         |         | | | | • Increases consistency and production of milk, especially in Summer  
|         |         | • Increased fertility rates in cows and buffaloes, while reducing mortality rates |
| National Institute of Animal Nutrition and Physiology (NIANP), Bangalore, South India | Public | Due to start project on probiotics; to develop a nanotechnology delivery mechanism | ICAR | Indian Institute of Science (IISc); involved in designing the delivery of the material and also characterization of the structures | • Fat and SNF, used as by-products for making sweets, sold to dairy and sweet vendors;  
• Product used by various dairy companies, such as Goku$^{100}$ and at military farms, which has 40,000 cows  
• To help better nutrition utilization and growth in poultry and therefore help increase farmers’ profit from poultry farming |

**Table 16: Nanotechnologies food and food packing projects and products in India**

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$^{100}$ A leading vendor of milk and milk-based products in India
APPENDIX 18: List of organisations/institutions for where participants were interviewed

The following lists provide only some of the names of organisations in Canada and India from where participants were interviewed (*signifies various departments).

<table>
<thead>
<tr>
<th>CANADA</th>
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<tbody>
<tr>
<td>GOVERNMENT AGENCIES/ORGANISATIONS</td>
<td>NOT FOR PROFIT ORGANISATIONS/ASSOCIATIONS</td>
<td></td>
<td></td>
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<tr>
<td>Health Canada (HC)</td>
<td>NanoQuébec</td>
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<tr>
<td>Environment Canada</td>
<td>Canadian Standards Association</td>
<td></td>
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<tr>
<td>Canadian Food Inspection Agency (CFIA)</td>
<td>Food &amp; Consumer Products of Canada</td>
<td></td>
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<tr>
<td>National Institute for Nanotechnology (NINT)</td>
<td>ACAMP (Alberta Centre for Advanced MNT Products)</td>
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<tr>
<td>Canada Foundation for Innovation (CFI)</td>
<td>Grain Growers of Canada</td>
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<tr>
<td>International Development Research Centre (IDRC)</td>
<td>The Packaging Association of Canada (PAC)</td>
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<tr>
<td>Industry Canada (IC)</td>
<td></td>
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<tr>
<td>Canadian Institutes of Health Research (CIHR)</td>
<td>PRIVeTE FIRMS</td>
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<tr>
<td>Standards Council of Canada (SCC)</td>
<td>Retailers/manufacturers</td>
<td></td>
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<tr>
<td>Alberta Innovates Bio Solutions</td>
<td>Nutraceutical company</td>
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<tr>
<td>NE’LS Network</td>
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<td></td>
<td></td>
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<tr>
<td>Department of Foreign Affairs and International Trade</td>
<td>UNIVERSITIES / RESEARCH INSTITUTIONS</td>
<td></td>
<td></td>
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<tr>
<td>Agriculture and Agri-Food Canada</td>
<td>University of Ottawa</td>
<td></td>
<td></td>
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<tr>
<td>National Research Council Canada</td>
<td>University of Guelph*</td>
<td></td>
<td></td>
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<tr>
<td>NGO/CONSUMER REPS</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>The ETC Group</td>
<td>Carleton University</td>
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<tr>
<td>Friends of the Earth</td>
<td>Canadian Irradiation Centre INRS-Institut Armand-Frappier</td>
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<tr>
<td>Consumers Council of Canada</td>
<td>W. Maurice Young Centre for Applied Ethics, University of British Columbia (now at a private consulting firm)</td>
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<tr>
<td>GOVERNMENT AGENCIES/ORGANISATIONS</td>
<td>UNIVERSITIES/RESEARCH INSTITUTIONS</td>
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<tr>
<td>National Academy of Agricultural Research Management (NAARM)</td>
<td>Tamil Nadu Agricultural University (TNAU)*</td>
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<tr>
<td>Ministry of Communications and Information Technology</td>
<td>Institute of Life Sciences</td>
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<tr>
<td>Central Food Technological Research Institute (CFTRI)</td>
<td>Indian Institute of Technology New Delhi*</td>
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<tr>
<td>Indian Council of Agricultural Research (ICAR)</td>
<td>Indian Institute of Technology Bombay</td>
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<tr>
<td>National Dairy Research Institute (NDRI)</td>
<td>PRIVATE FIRMS</td>
<td></td>
<td></td>
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<tr>
<td>National Institute of Animal Nutrition and Physiology (NIANP)</td>
<td>Small and larger firms</td>
<td></td>
<td></td>
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<tr>
<td>Central Institute for Research on Cotton Technology (CIRCOT)</td>
<td>Firms promoting nanotechnology</td>
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<td></td>
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<tr>
<td>Indian Institute of Toxicology Research (IITR)</td>
<td>NOT FOR PROFIT ORGANISATIONS/ASSOCIATIONS</td>
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<td></td>
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<tr>
<td>Council of Scientific and Industrial Research (CSIR)</td>
<td>TUV India Pvt. Ltd</td>
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<tr>
<td>Central Institute of Fisheries Technology (CIFT)</td>
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<tr>
<td>Indian Institute of Packaging</td>
<td>Federation of Indian Chamber and Commerce Industry (FICCI)</td>
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<tr>
<td></td>
<td>NGO</td>
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<tr>
<td></td>
<td>An NGO working with farmers</td>
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</tbody>
</table>

*Table 17: Names of organisations from where participants were interviewed*
APPENDIX 19: Findings in Canada that relate to the research sub-question

Figure 24: Findings in Canada that relate to research sub-question 1
Figure 25: Findings in Canada that relate to research sub-question 2
APPENDIX 20: Findings in India that relate to the research sub-question

Figure 26: Findings in India that relate to research sub-question 1
Figure 27: Findings in India that relate to research sub-question 2
APPENDIX 21: Request for interview letter

Dear Mr./Ms. (name),

I am a PhD research student at the Manchester Institute of Innovation and Research (MIoIR), Manchester Business School, University of Manchester, UK. I am writing to request you for an interview for my research in “Responsibility, Regulation and the Construction of Markets for Nanotechnologies in Food and Food Packaging: Cases of F&FP in Canada and India”.

The study is expected to investigate the idea of ‘responsibility’ for the safe and ‘responsible’ development of nanotechnology through the lens of perspectives of different actors and stakeholders through the value chains, with a particular focus on F&FP products. It will pay particular attention to the role of intermediaries (whether point of sale engagement with end customers or via catering and restaurant establishments) – to date ‘invisible’ actor groups in discussions about governance of nanotechnology. Research in comparative national settings is also envisaged on the grounds that regulation of nanotechnologies differs significantly across countries, and thus impacts value chains differently. A comparative case study analysis will be undertaken with India, an OECD-interest and potential example of a country with limited/low regulatory standards, and Canada, an OECD country considered potentially to have high regulatory standards. The study will help to understand the culture and progress towards responsible innovation within these countries (keeping in mind that these markets play a key role in globalization) and provide useful insight into the growing trends of nanotechnologies in the food and retail sectors in emerging and developed markets.

As someone with extensive experience and knowledge, I believe that you could provide me with valuable information and insights in this area. I am not seeking any information that might be regarded as commercially or technologically confidential - instead, I am seeking an overview of the issues from your perspective to help me develop an informed overview of the subject.

I would very much appreciate therefore if you could provide me the opportunity to speak with you, by telephone sometime this week/next week, if possible, or at a time convenient to you in the near future. Alternatively, I will be visiting Canada for this research in June/July and I would be happy to meet you in person.
By way of background on myself, I have conducted a series of studies in the area of nanotechnologies. I was involved in the research project and report writing for the study “Top Performing Cluster in the UK - Nanosciences & Nanotechnologies, the case of Manchester”, for the National Research Council Canada (NRCC), of which I was the co-author of the final report. I was also involved in the European Commission’s FP7 NANOPLAT project (www.nanoplat.org), where the University of Manchester was responsible for the package of work which involved interviewing and mobilising stakeholders from industry, universities, policy and standards agencies, and NGOs across Europe.

I have attached a Participant Information Sheet and the research abstract, which provides further details about my research and interview process. If there is anything else you require to make your decision, please do not hesitate to contact me via email XYZ@...com or by phone +44 XXX XXXX XXXX. I would be happy to submit additional information. I do hope that you are able to spare the time to help me with this research.

I look forward to hearing from you.

Kind regards,

Rumana Bukht