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Nanotechnologies and new dynamics in risk management: looking at institutional emergence and public engagement experiments

Introduction:

This paper explores new dynamics in risk management by focusing on the case of the development of nanotechnologies. The development of any new technology raises issues relating to the process of measuring or assessing risk and developing strategies to manage it (Cothern, 1995; Johnson & Covello, 1987; Singh, 2006; Vogel, 2003). The difficulty with nanotechnologies is that it is at present extremely difficult to measure or assess the risks linked with the development of nanostructures. Nanotechnology refers to the science and technology of developing new materials and devices by working at the atomic and molecular level, typically defined as at a scale which is inferior to 100 nanometres in one dimension

(1nm:10^{-9} metres). In many cases, materials that are sub-divided to a nanometric scale display different behaviours than their bulk counterparts. The bases for such nano-effects remain an active topic of research but include a higher relative dominance of surface reactivity, quantum confinement of electrons that lead to phenomena such as narrow bands of fluorescence, and a size scale that is comparable to that of many biomolecular structures. The unique properties of nanoscale materials are inspiring a wide range of applications that span computer storage, semiconductors, medical treatments, advanced manufacturing and energy. The differences between materials in their nano- and bulk- formats that make them of interest in new applications also suggest that these materials may interact differently with ecosystems and living cells. The development of nanotechnologies seems to raise as much hype as fear concerning its future impact on society: on the one hand, it lies at the core of technological innovations said to have the potential to revolutionize society so deeply as to bring a new post industrial era; on the other hand, it raises questions linked to ethics, to the management of the unknown, to potential harms in a way that has been suggested to be entirely new. Drawing from this highly topical empirical context, in this work we analyse changes in risk management that consider potential benefits and risks associated with these emerging technologies. We first consider factors that may set apart nanotechnology applications from previous innovations, particularly in terms of metrology and risk assessment. We then analyse two sets of public engagement experiments undertaken in the last five years in the nanotechnology field and how these relate to the emergence of a new type of institutional framework around the development of nanotechnologies. We observe that in the area of risk management, the development of nanotechnologies appears to be generating a mechanism for aggregating the expectations of various stakeholders, resulting in a new form of institutionalisation that grows out of previous, largely negative, experiences with technological innovation.

The paper is firmly anchored in institutional theory. It integrates the findings of institutional economics which establish relations between the performance of economies and institutions and institutional change (North, 1990). Institutional theory also provides the theoretical model of analysis for the process of institutional construction around the development of nanotechnologies (de-Holan, 2004; Lawrence, Hardy, & Phillips, 2002; Lawrence & Phillips, 2004; Lawrence, Phillips, & Hardy, 1999; Lawrence & Suddaby, 2006; Lounsbury, 2007; Phillips & Brown, 1993; Phillips, Lawrence, & Hardy, 2004; Tracey, 2005).

Context:

Nanotechnology is a generic word that refers to products and technologies involving the manipulation of matter at the level of atoms and molecules, at the scale of the nanometer (nm), i.e. of a billionth of a meter (10^{-9} m). Manipulating matter at such a scale seems to open up endless possibilities, because the particles that are obtained have new properties which often did not exist before. People have heard about dirt-resistant window panes and transparent sun blocks, but the applications are far more diverse. Unlike information technologies or biotechnologies, nanotechnologies do not represent a single sector of innovation or application. Indeed, nanotechnology might be better described as an approach that spans many sectors including biotechnology, molecular electronics, materials science, and chemical processing to name a few. The nanomaterials sector is by far the most developed manifestation of the emerging nanotech industry, and these new materials are making their way in to a wide range of products. The current paper focuses on the nanomaterials/ nanoparticle industry. Three major fields of application for these materials are: the health sector, military applications and sustainable development through the development of new or better solutions in areas as varied as water treatment, electronics or energy - production, storage and distribution. Examples like the fabrication of nano-based ceramic membranes for water treatment or new fuel additives to reduce energy consumption or pollution show how nanotechnologies can contribute positively to extend environmental responsibility. At the same time, it is inevitable that the production of significant quantities of nanomaterials will result in their introduction to the atmosphere, hydrosphere, and biosphere. The full consequences of this introduction have yet to be determined. One concern has been that, due to their size nanoparticles may pass through filters and cell barriers. Two recent studies, related in the source of nanoparticles used in the experiments, concluded that colloidal aggregates of the fullerene C_{60} (referred to as nC_{60}) produced oxidative damage in the brains of largemouth bass (Oberdorster, 2004) and relatively high toxicity in experiments with human tissue cultures (Sayes et al., 2004). A mechanism of reactive oxygen production by the C_{60} and its subsequent attack on lipids in cell membranes was proposed to explain these results. However, the methodologies for exposure used in these studies do not represent environmental conditions and the preparation of the nC_{60} raises serious questions as to whether the observed effects stemmed from the fullerenes themselves or from the organic solvents used in preparing the nC_{60}. Other studies have noted the transport of gold nanoparticles through the placenta of pregnant mice to reach their foetuses (Bergeron & Archambault, 2005) and the passage of nanoparticles across skin and the blood-brain barrier. Although it is not yet possible to generalize on the toxicity or the characteristics of nanoparticles that may be associated with toxicity, it is clear that the health and environmental effects of these materials will not be uniform.

What do these particular features mean in terms of risk management?

Firstly, it must be said that as nanotechnologies are beginning to diffuse very broadly, there are numerous stakeholder groups that are affected by them. These stakeholder groups have their respective value systems to characterize the importance of various parameters. Start-up nanotechnology companies see the great benefits of the growing markets for their products. Users of products containing nanomaterials – notably in the health sector – want to enjoy the benefits of the new products but are very concerned about the safety of being exposed to them. Insurance companies need to know how much to charge for premiums based on the risk they are taking on when insuring the nanotechnology industry. The general public experience positive changes enabled by engineered nanostructures but are impacted in some way by nanomaterials entering the air, water, soil, and organisms around them. Managing nanotechnology-related risks is made complex by the necessity to integrate the perspectives of these different stakeholder groups with their varying value systems and priorities.

Secondly, risk is a function of hazard and exposure and there is great uncertaintly regarding both of these factors. So to evaluate risk, the effects of a substance must be combined with the likelihood that it will come in contact with the environment. In order to understand the impact a material may have on its surroundings, it is necessary to know how dangerous it is, as well as how it will interact when released to the environment. Where will it go, in which media will it tend to collect, with what organisms will it be likely to make contact, and to what extent will it have toxic effects on them when that contact occurs? This information must be combined with data about the amount of the material and the conditions in which it is being handled or produced. In order to combine risk with exposure it is necessary to evaluate the probability of substance release as well as the quantity involved. An appropriate algorithm can be used then to combine these factors and determine the resulting relative impact of the material, but one sees the complexity of the task given the current technical difficulties to monitor nanoparticles. The application of risk assessment methods used in industry is directionally helpful, but it is important to recognize that the full impacts will not be adequately captured solely via application of existing assessment methods to these novel materials. The composition of nanomaterials may closely resemble known bulk materials, but their properties do not hold constant as size scales down; instead they exhibit distinct properties due to their small size, shape and surface functionalities. This is precisely what makes engineered nanomaterials so interesting. However, this is also why modifications to the current assessment criteria need to be explored. One example is the current REACH regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals), which was put into place in 2007 to replace 40 existing legal acts and create a single system for **all** chemical substances. The REACH regulation requires manufacturers and importers to gather comprehensive information on the properties of all substances produced or imported in quantities higher than 1 ton per year and to submit the necessary information to demonstrate their safe use in a registration dossier to the European Chemicals Agency. However, because of the size of nanoparticles, nanoproduction tends to fall into the realm of kilos, not of tons.

Besides, the particular properties and behaviors used until now to characterize the impacts of a chemical are not always adapted to the description of impacts of nanomaterials. This means that modifications to current assessment criteria need to be explored and that a key to successfully manage nano-related risks will be to choose the appropriate parameters and the appropriate methodology for combining them.

The case:

The previous paragraph outlined the very specific features of nanotechnologies: having the potential to revolutionize society, and also having inherent properties which implied a new approach of risk management. How do these features influence the institutionalisation of the field in the area of risk management? In fact, governments were rapidly aware of the necessity to study the societal implications of the development of these new technologies. Because of the widespread use of the internet and the growing concern of the general public for sustainable development and technological issues, there were also other moves to look into the matter parallel to the institutional moves. In the next paragraphs, we study two sets of public engagement schemes which cover interactions between these governmental and non-governmental initiatives and show how they contribute to shape the institutionalisation of nanotechnology and produce new dynamics in risk management.

In his analysis of institutions and organisations, Scott delved into the concept of institutional pillars (Scott, 1995). Chronologically, it seems that it was North America and the UK who produced the first bases of two pillars of the institutionalisation of nanotechnology: an institutional pillar-base and a non-governmental pillar base.

Institutional pillar-base, phase one:

In 2001, the US created a single agency centralizing the major research efforts relating to nanotechnology, the NNI (National Nanotechnology Initiative). Before this decision, nanotechnology R&D was a haphazard smattering of various unconnected initiatives, in the US and everywhere else. The NNI pursued the following aims:

1. Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology
2. Facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit
3. Develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology
4. Support responsible development of nanotechnology (souce: www.nni.org, accessed July 2006).

The report published in May 2005 by the US President’s Council of Advisors on Science and Technology ((PCAST (President's Council of Advisors on Science and Technology), 2005) found that the U.S. was the world leader in nanotechnology as well as the acknowledged leader in nanotechnology research and development. The approximately $1 billion the Federal government spent on nanotechnology R&D in 2005 was roughly one-quarter of the current global investment by all nations. Total annual U.S. R&D spending (Federal, State, and private) stood at approximately $3 billion, or one-third of the estimated $9 billion worldwide spending by the public and private sectors combined. In addition, the United States led in the number of start-up companies based on nanotechnology, and in research output as measured by patents and publications. It concluded that the NNI appeared well positioned to maintain United States leadership going forward thanks to its coordinated interagency approach to planning and implementing a Federal R&D program and recommended continued robust funding for the NNI.

The creation of the NNI was followed by the publication of the S 189 Act (US Congress, 2003) which defined the program in section 2, as:

> (10) ensuring that ethical, legal, environmental, and other appropriate societal concerns, including the potential use of nanotechnology in enhancing human intelligence and in developing artificial intelligence which exceeds human capacity, are considered during the development of nanotechnology by:
>
> (A) establishing a research program to identify ethical, legal, environmental, and other appropriate societal concerns related to nanotechnology, and ensuring that the results of such research are widely disseminated;
>
> (B) requiring that interdisciplinary nanotechnology research centers established under paragraph (4) include activities that address societal, ethical, and environmental concerns;
>
> (C) insofar as possible, integrating research on societal, ethical, and environmental concerns with nanotechnology research and development, and ensuring that advances in nanotechnology bring about improvements in quality of life for all Americans; and
>
> (D) providing, through the National Nanotechnology Coordination Office established in section 3, for public input and outreach to be integrated into the program by the convening of regular and ongoing public discussions, through

mechanisms such as citizens' panels, consensus conferences, and educational events, as appropriate.

With the creation of the NNI and the following S 189 Act, the US set a double trend: the need to coordinate all nanotechnology research, and the necessity to assess and address societal implications all along the way of the development of nanotechnologies. This was the first basis of the institutional pillar of the institutionalisation of nanotechnologies. In the wake of the American launch, most countries, and regional powers like the EU, saw the importance of coordinating nanotechnology research and giving it some guidelines. Yet nowhere did the word 'risk' appear in these US texts institutionalizing nanotechnology as a coordinated national enterprise.

Non-governmental pillar-base, phase one:

Just as these important institutional steps were taken, on the non-governmental level, in 2002, the Canadian-based NGO, the Action-Group on Erosion, Technology and Concentration (the ETC Group) released a report called 'No Small Matter' in which it asked for a moratorium on the commercialization of new products containing novel, engineered nanoparticles until lab protocols were established to protect workers, and until regulations were in place to protect consumers and the environment. (ETC Group, 2002). This could be seen as the source of the non-governmental pillar base. The ETC Group was indeed the first NGO to draw attention to potential problems linked with the development of nanotechnologies. Interestingly, the word 'risk' did not appear once in this first text either.

Institutional pillar-base, phase 2:

After North America, the UK government commissioned in 2003 the Royal Society and the Royal Academy of Engineering to study potential applications of nanotechnology and their possible environmental, health and safety, social and ethical implications. The report was published in 2004. It referred to the call for a moratorium by the ETC Group (chapter 8, paragraph 51) and included questions about some risks posed by manufactured nanoparticles and arguments on the need to review chemical regulations to ensure that they encompassed nanotechnologies. In its final chapter, recommendations, the word 'risk' appeared four times, but in chapter 8, the chapter dealing with regulatory issues, the word appeared 29 times. The report also mentioned the importance of public and stakeholder dialogue at the early stages in the development of nanotechnologies. Professor Dowling, the coordinator of the report, said:

> "There is a gap in the current regulation of nanoparticles. They have different properties from the same chemical in larger form, but currently their production does not trigger additional testing. It is important that the regulations are tightened up so that nanoparticles are assessed, both in terms of testing and labelling, as new chemicals."

The report did not find any justification for imposing a ban on the production of nanoparticles. However, as a precautionary measure it recommended that releases to the environment be minimised until effects were better understood. The report also recommended that the UK Government should initiate a properly funded public dialogue around the development of nanotechnologies at a stage when such discussions could inform key decisions about their development and before deeply entrenched or polarised positions appeared.

Non-governmental pillar-base, phase 2:

In 2003, the NGO the ETC Group published a new report in collaboration with a renowned toxicologist, Dr Vyvyan Howard (ETC Group, 2003). The report included a literature search relating to the effects of nano-sized particles on human health and the routes by which nanoparticles can enter the body, and mentioned the word 'risk' 14 times. Another report published earlier that year, *the Big Down*, showed 30 mentions of the term (Mooney, 2003).

Institutional emergence:

It was during the two-year period 2002-2004 that the concept of risk emerged in relation to the development of nanotechnologies. It was also at the same time that the first experiments of public engagement were launched. This particular form of institutional emergence was explained by various factors:

- There was a genuine desire of governments to 'do things right' from the start (European Commission, 2004; European Union, 2003; US Congress, 2003).
- Previous academic studies had shown the importance of involving the public into policy making in the face of technological uncertainty (Auplat, 2006; Callon, Lascoumes, & Barthe, 2001; Fiorino, 1990; Godard, Henry, Lagadec, & Michel-Kerjan, 2002).
- The industry was very wary not to repeat the same mistakes that had hampered the development of biotechnologies (Auplat, 2006; Chataway, Tait, & Wield, 2006; Gaskell, 2004).
- The insurance sector was very cautious and expressed concern at covering products that might turn into asbestos-like problems (Swiss Re, 2004).

In the next part, we focus on the public engagement experiments to explore what role they actually play in this institutional emergence.

Methodology :

Our methodology is as follows. We draw from various archival sources, and particularly from two reports, one from the UK and one from France, to establish a panorama of existing public engagement experiments undertaken in the last five years in the nanotechnology field. This data concerns essentially European and American experiments, as there do not seem to have been many other experiments of consequence elsewhere in the period concerned. We synthesize the various features of each type of experiment, checking our findings with focused interviews with key stakeholders of the public engagement experiments. Finally, we draw conclusions about new dynamics in risk management.

In 2005 the UK government published its Outline Programme for Public Engagement on Nanotechnologies (OPPEN) as a response to the report from the Royal Society and Royal Academy of Engineering (HM Government in consultation with the Devolved Administrations, 2005). One of the parts of this programme was to fund a study of public engagement initiatives and NEG (the Nanotechnology Engagement Group) was established for this purpose. NEG's objective was to document the learning from a series of attempts to involve members of the public in discussions about the development and governance of nanotechnologies, and it did so in its report published in 2007, *Democratic Technologies?* (Gavelin, Wilson, & Doubleday, 2007).

In France, the Department of Higher Education and Research and the Department of Industry commissioned in 2006 a report gathering the recommendations of the main nanotechnology stakeholders to get a picture of their positioning and recommendations towards nanotechnology (Cité des sciences et de l'industrie, 2007). The report – entitled *'cahiers d'acteurs'* – was composed of 14 chapters, each one an independent report issued by one group of stakeholders. The stated objective was to gather the analyses of 'the main stakeholders: industry, science and politicians'. Interestingly, no mention was made of the opinion of citizens. However, half of the reports involved public engagement experiments. One of the major differences between the *cahiers d'acteurs* and *Democratic Technologies* reports is that the former is a gathering of primary sources, as each of the 14 chapters comes directly from the stakeholders themselves, whereas the latter speaks through the voice of the NEG's authors, as it is a digest of the various experiments they studied.

According to the NEG's report there had been at until 2007 some twenty public engagement initiatives on nanotechnologies internationally. The report may not have accessed all available information, but it did not mention any initiative in Asia or the Middle East. Out of 23 projects identified involving public engagement, 14 came from EU countries, 6 from North American countries, and 3 from Australia and New Zealand. Public engagement was defined as the different ways that institutions interact with the general public outside of formal democratic structures such as elections. The NEG study focused exclusively on forms of public engagement that involved dialogue between members of the public and scientists or decision-makers, and excluded purely one-way forms of public engagement such as information campaigns or public opinion polls. The scope of the projects varied a lot, from a one day workshop to five-year projects and they spread out in time from 2003 to 2006. Sticking to NEG's definition of public engagement, out of the 14 initiatives documented in the '*Cahiers d'acteurs*', 7 focused on programmes involving public engagement. There were some overlaps between the two reports' studies, and we identified a total of 25 different experiments meeting NEG's definition of public engagement, from which we drew our empirical data and established a typology of the major public engagement initiatives in relation to nanotechnology from 2003 to 2007.

Typology:

Games and scenario playing:

The first public engagement project – in 2003 – was in the form of a game commissioned by the EU sixth Framework programme and the Wellcome Trust. It was a nanotechnology version of the Democs game. The Democs game (deliberative meeting of citizens) is produced by the New Economics Foundation (nef) as a policy-making tool to enable small groups of people to engage with complex science-related public policy issues. Participants are dealt a series of hands of cards to read, and are asked to pick the ones that they feel are most important for the discussion. At the end of the game participants state their preferred policy position on a subject by choosing from four pre-developed policy positions or developing one of their own. The games usually involve teams of six to nine people. See: www.neweconomics.org, the website of nef, the British think-tank founded in 1986 which develops the various versions of the Democs game.

In another experiment in Australia, participants were divided into small working groups and were given a hypothetical scenario kit to stimulate discussions about the social, economic and environmental implications of nanotechnology. This experiment was supported by CSIRO, the Commonwealth Scientific and Industrial Research Organisation, Australia's national science agency. The participants selected included community members, CSIRO staff, nanotechnology specialists and government representatives. See www.minerals.csiro.au

Nano juries:

This experiment, run in 2005, resulted from a collaboration between Cambridge University Nanoscience Centre, Greenpeace UK, the Guardian and the Policy, Ethics and Life Sciences Research Centre (PEALS) at Newcastle University. Modelled on legal trial juries, the experiment brought together a group of sixteen participants from a West Yorkshire borough – the jurors – selected from the electoral register and via suggestions from youth and community workers. Before turning to nanotechnology, the jury addressed a topic of their choice over eight evening sessions of two and a half hours each. They decided to look at young people, exclusion and crime in the local community. They then discussed nanotechnologies in a further ten sessions of two and half hours each. Six witnesses selected by an oversight panel provided evidence and in the last few sessions the jurors wrote recommendations for the future development of nanotechnologies in the UK. The recommendations were presented to an audience of policy-makers, scientists, journalists and social researchers at an event in London in September 2005. See www.nanojury.org.uk

Deliberative public debates:

The format is to have experts and specialists invited through organisers' networks come and give evidence on various aspects of nanotechnology, and then open discussions with the floor. The audience comes freely and most people attending have an interest or are involved in nanotechnologies. In the case of the French experiments, every meeting was about two and a half hour long and a report was released after each debate. A series of recommendations followed the debates, addressed specifically to policy makers, industry leaders and academics. See the reports coming from the Nanoviv debates and from the Nanomonde debates, www.vivagora.org; See also the report of the

Citizens' panels:

These experiments are situated half-way through nanojuries and deliberative public debates. Self-selected participants heard presentations by expert witnesses offering three different perspectives on nanotechnology: industry, government and community. This was followed by discussions and at the end of the workshops the participants formulated collective recommendations. For examples, see Melbourne's citizens' panel on nanotechnologies, www.minerals.csiro.au; see consultation citoyenne EPE-APPA sur les questions environnementales et sanitaires liées au développement des nanotechnologies, see conference de citoyens sur les nanotechnologies, a conference run by the 'Ile de France' region in France, see la conversation de la maison Midi-Pyrénées: contribuer à l'éclairage de la decision publique, l'exemple des nanotechnologies, see NanoDialogue, a programme funded by the EU 6th Framework Programme www.nanodialogue.org; see Madison Area Citizens' Conference on Nanotechnology, website : http://cdaction.org/nanotechnology_citizen_conference.html

Online consultations and interactive assessment tools:

This methodology for public engagement is gaining ground, and is more and more routinely used in conjunction with each of the other types of experiments. Websites offer information about nanotechnologies, as well as interactive more or less constructed spaces for chats or debates. Unfortunately at the time of writing this paper it has not received sufficient feedback to draw valid conclusions. See for example the Nanologue project organised by the Forum for the Future (UK), Wuppertal Institute (Germany), EMPA (Switzerland) and Triple Innova (pan-European), funded by the European Commission 6^{th} Framework Programme, www.nanologue.net, or the Global Dialogue on Nanotechnology and the Poor (GDNP) organised by the Meridian Institute, USA, and funded by the Rockefeller Foundation (USA), the International Research Center (Canada) and the Department for International Development (USA), www.meridian-nano.org .

Interpretation:

Apart from the different formats outlined above it is worth noting some general features of the public engagement experiments. In the vast majority of cases, the public knew nothing about nanotechnologies beforehand. Only 4 percent of the experiments concerned stakeholders who had a direct involvement in nanotechnologies, and in these cases, the involvement was scientific rather than industrial or governmental.

In most cases, participants engaged themselves on a voluntary base, although NEG documented experiments where the public were paid to participate or were enticed to take part by other means (for instance to talk about other subjects that deeply concerned them).

A big difference in the experiments was whether the thinking was directed or not. In the scenario-playing, games options, nano-juries and citizens' panels the participants had to choose solutions from various options that were presented to them, which meant that their contribution was in fact in the form of a reaction to ideas that were submitted to them. Conversely, in the deliberative public debates and to a certain extent online consultations and interactive assessment tools, their participation was allowed to be more open. This distinction between open discussion and closed discussion, where the public is asked to *react* to scenarios or to given information, is an important one. Indeed, history has shown that some of the societal issues of past technological innovation had not been anticipated by the scenarios of scientists or the early developers of these technologies. For instance, with biotechnologies, it was farmers' associations who first mentioned some of the risks associated with gene patenting like the loss of cultural heritage for some nations, or the issue of the ownership of the living. It was also non-specialists who drew attention to the risks coming from the cohabitation between genetically modified crops and non-genetically modified ones.

Finally, experiments fell into two categories, those coming from institutional sources (mainly government or science and research) and those coming from civil society, usually local community groups or groups with environmental preoccupations. A word here must be said of an experiment of a unique nature, that of *Cahiers d'acteurs N°13.* This report came from a gathering of trade unions representing workers with nanotechnology-related activities. In this particular case, the stakeholders did have knowledge of nanotechnologies, and a particular involvement with the technology.

The outcomes of these various public engagement experiments could be summarized as follows:

1. Given the various differences outlined above (public engagement formats, locations, participants etc.) the outcomes were on the whole rather homogeneous. The same types of preoccupations, although not phrased identically, emerged.
2. On the whole, nanotechnology was perceived as a highly interesting area of innovation with a great potential for the improvement of society.
3. Risk management was seen as one of the key issues of the development of nanotechnologies.
4. There was consistent demand to accompany the development of nanotechnologies with societal assessments and public engagement.

Risk itself was defined differently by the various groups with various salient points:

1. Most saw risks in relation to the usage of nanomaterials. In this understanding of risk, three subcategories emerged: health and especially human health risks, risks of a degradation of the environment, and finally risks of loss of freedom coming from the possibilities of miniaturization of monitoring devices. Within this understanding of risk, for most, the important thing about risk management was to assess the risk/benefit ratio, taking time into account, as well as *whom* risks and benefits were most likely to affect. In a lot of the reports there was a sentiment that risks might have more impact on less developed countries and more benefits for more developed countries. Participants stressed the necessity to make sure that risks/benefits were distributed equally among more and less developed countries. Although in

some cases the debate was introduced especially in the form of ‘how to improve *British* society’, in all the experiments the answers were invariably of global purport.

2. The second understanding of risks was in relation to policy making. Many groups vented concern that the industry, politicians and regulators might not show enough transparency for various reasons in the processes leading to decision making. The major concerns were twofold:
    - How to reconcile the fact that the industry – in the most general acceptance of the term – needed to preserve some secrecy on some processes in order to maintain a competitive advantage, and expectations of public information.
    - How to make sure that policy makers and regulators really understood and controlled the various aspects of the development of nanotechnologies.

These preoccupations did not correspond to clear-cut groups of stakeholders and spanned various groups. Similarly, calls for more regulation or for a moratorium on nano-research did not correspond to any particular group. When calls for more regulation were made, they were in line with the understandings of risks outlined above and covered the following areas:

1. The chemical classification and labelling of nanoparticles as well as regulation to monitor nanoparticles releases in the environment.
2. The mechanisms of transparency in regulation and policy-making.
3. The safeguarding of personal liberties.

Conclusions:

We observe that in the area of risk management, the development of nanotechnologies appears to be generating a mechanism for aggregating the expectations of various stakeholders, resulting in a new form of institutionalisation that grows out of previous, largely negative, experiences with technological innovation. What really made a consensus in all the public engagement experiments was the need to weigh the risks and benefits of the new technologies for society before bringing them to the market, and to make sure that the benefits really outweighed the risks for all. It appeared that what was at the root of public concern was not so much scientifically defined risks to human health or the environment as the need to know whether a new technology risk/benefit ratio would be clearly in favour of long term benefits for society in general. The public engagement experiments also showed that what the public expected from regulation was the capacity to anticipate and provide a frame of action to future potential consequences.

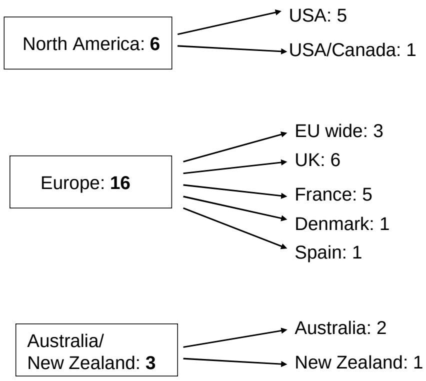
The fact that these public engagement experiments take place, coupled with the development the internet and its multiplier effect on the shaping of public opinion shows how different risk management has become from what it was only ten years ago. From the top down approach that was used in the development of previous innovative technologies (Irwin, Jones, & Stilgoe, 2006), regulators now move towards a more inclusive way of policy making which gives a new weighting to technological and societal parameters.

The major finding of the paper is that a traditional top down approach of risk management alone is likely to be insufficient in addressing the concerns raised by emerging nanotechnologies. It also highlights that technology and society run on a system of checks and balances: in the constant and parallel evolution of both technology and society, society ratchets-up technological innovation, using the latest technological developments to safeguard itself against other possible technological dangers. This is what underscores the trends in nanotechnology risk management and regulation.

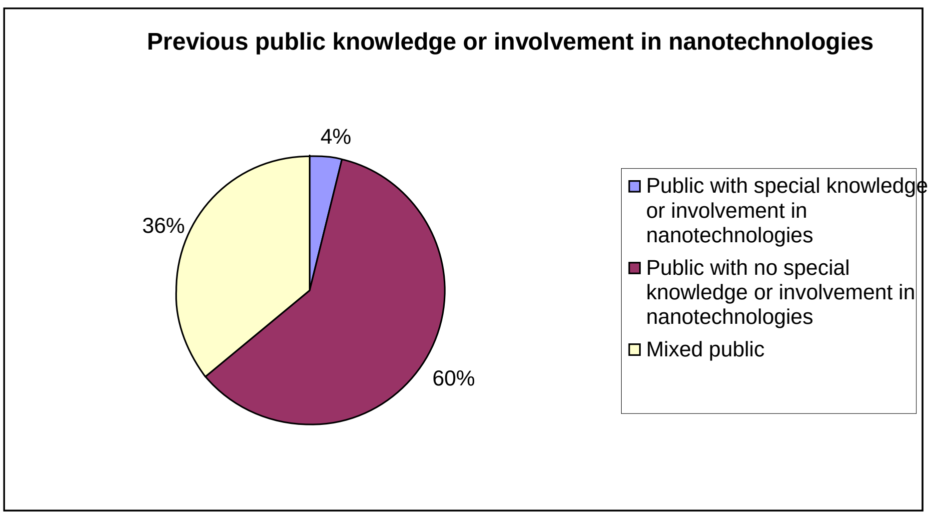
The paper makes the following contributions: firstly it confirms previous studies which show that society plays an important regulatory role in innovation (Chataway et al., 2006; Jaffe, Newell, & Stavins, 2005). Secondly, in studying the relations between technological innovation and the shaping of institutional structures, it provides new insights into the emergence of institutions. In particular, by placing the construct of a new form of risk management at the core of institutional emergence, it provides a fresh approach to institutional theory. It also extends the emerging body of institutional theory literature which explores how institutional change is emergently produced by heterogeneous activity at various locations by actors with varying kinds and levels of resources. Finally, by assessing the relative importance of the characteristics of nanotechnologies in the design of an institutional framework for their development – particularly in the areas of risk assessment and management – it sheds new light on the links between institutions and technology (Wiesner, Lowry, Alvarez, Dionysiou, & Biswas, 2006)

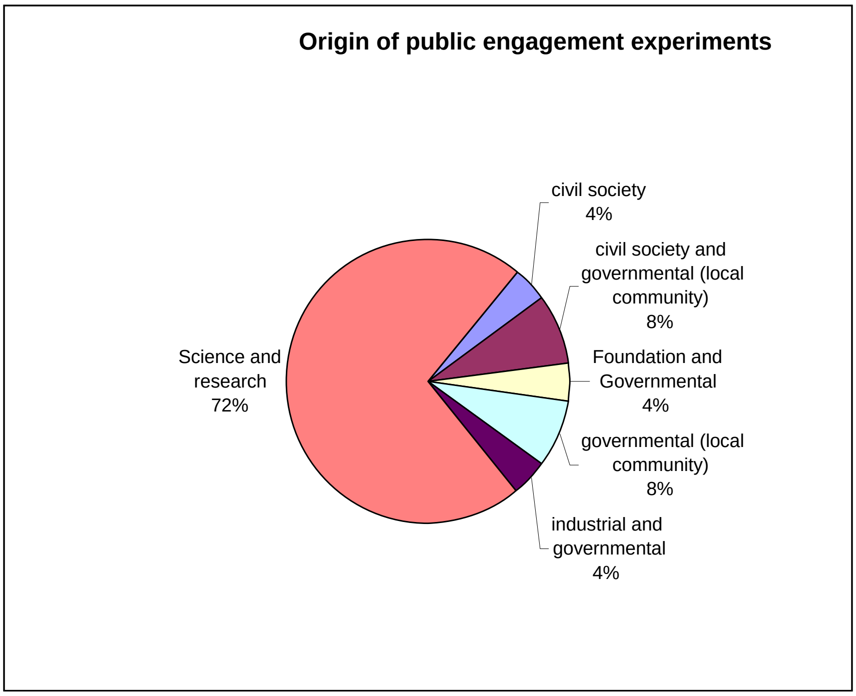
ANNEXES

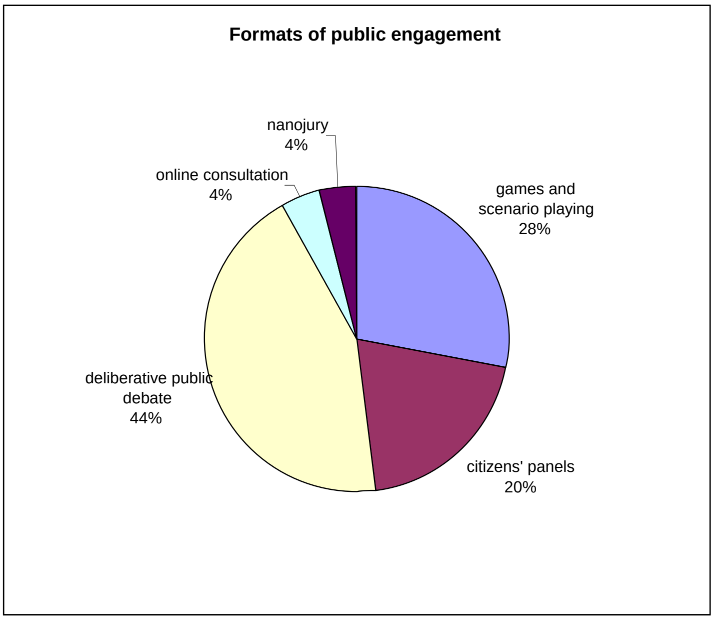
Countries involved in public engagement experiments: 2003-2007

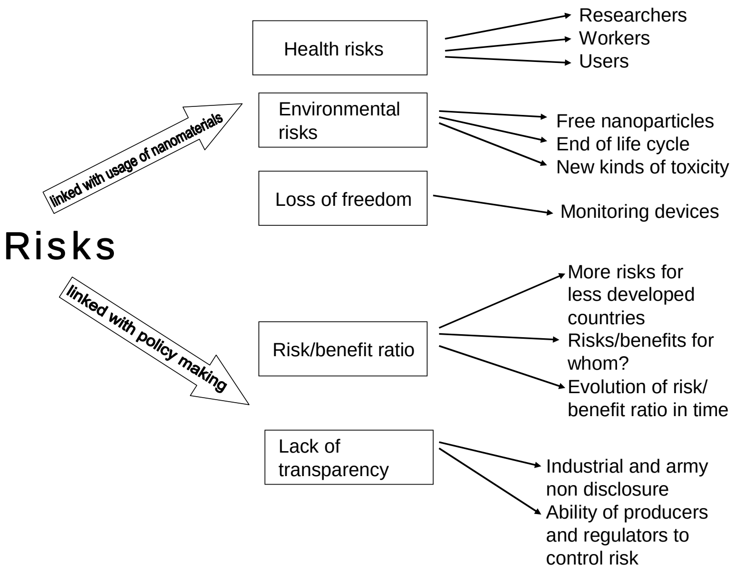


Data sources: NEG and Cité des Sciences & de l'industrie




Origin of public engagement experiments
civil society
4%
civil society and
governmental (local
community)
8%
Foundation and
Governmental
4%
governmental (local
community)
8%
industrial and
governmental
4%
Science and
research
72%


Formats of public engagement
nanojury
4%
online consultation
4%
games and
scenario playing
28%
deliberative public
debate
44%
citizens' panels
20%



Summary of nanotechnology risk analysis based on the various public engagement experiments studied.

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