Nanotechnologies for Tomorrow's Society[1]

A case study from the heart of Europe

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Abstract

Policy makers involved in innovation policy and scientists working on newly emerging technologies, such as nanotechnologies, are confronted with three broad categories of uncertainties: the lack of distinct indicating directions of possible applications (strategic uncertainty), the lack of scientific knowledge (complexity) and the ambiguous reception of new developments in society. In this climate of uncertainty and ambiguity it is by no means clear for the actors involved how to innovate purposefully and constructively. In response to such problems and difficulties, the interdisciplinary research project 'Nanotechnologies for Tomorrow's Society' (NanoSoc) engages innovation networks where each actor contributes his (incomplete) views and perspectives and confronts them with those of others. The project brings together nanotechnologists, natural and social scientists, stakeholders, and citizens in the region of Flanders, Belgium, to discuss and steer future nanotech developments in three particular fields of nanotechnology development: smart environment**,** bio on chip, and new materials. The research endeavour is a joint undertaking of the University of Antwerp, the University of Leuven, and the leading independent research center on micro-electronics and nanotechnology, IMEC. This paper addresses the three categories of uncertainties related to current nano-research in relation to current Flemish and European innovation policy and risk assessment approaches.

Keywords: nanotechnology, innovation policy, technology assessment, reflective action research

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[1] This conference paper bundles the concepts of a forthcoming article by Prof. Dr. Lieve Goorden, who coordinates the NanoSoc project, and the other authors.

Introduction

Nanoscience and nanotechnology as such do not exist. They are umbrella terms, resulting in the convergence of several natural science disciplines (chemistry, physics, and biology) and engineering. Nanotechnologies are most commonly defined as 'the research and development at the atomic, molecular, or macromolecular level using a length scale of approximately 1 to 100 nanometres in any dimension' (EPA, 2005). They imply the creation and use of structures and systems that have novel properties and functions because of their small size and the ability to manipulate and control matter on an atomic scale. The applications of this enabling technology promise to have a major impact on a broad range of areas including medicine, food and agriculture, information and communication devices, materials, defence, environment and energy. Nanosciences and nanotechnologies are a broad and interdisciplinary area of research where physicists, chemists, engineers, medical scientists and biologists work together in fields ranging from biology to materials sciences. This wide variety of possible applications should always be in the back of one's mind when talking about uncertainties, economic, ecological or societal advantages and risks.

Science, technology and society do not exist independently of each other. Hence, scientific discoveries and technological progress by themselves rarely create changes without co-evolutions or breakpoints in society. In other words, it is the confluence of old and new technologies with old and emerging social needs that creates changes (Carroll, 2001). The actions between different actors in the scientific community, adhering to the rules of contemporary paradigms, have a dynamic nature. It is by no means clear what rules (should) apply in complex issues such as newly emerging technologies, in order to have an appropriate interaction between scientists, technologists and society.

As with all new technologies, initial research on the nanoscale is somewhat chaotic and there are still many uncertainties and unknowns. New technologies could affect society in ways that are not intended by those who initiated them. Sometimes these unintended consequences are beneficial, such as in the creation of spin-offs with valuable applications in fields remote from the original innovation (Arnall, 2003). It is however, important to make a distinction between uncertainty and ambiguity. Uncertainty refers to a situation of unclearness about factual statements; ambiguity to a situation of contested views about the desirability or severity of a given hazard. Uncertainty can, in principle, be resolved by more cognitive advances (with the exception of indeterminacy), whereas ambiguity only by discourse. Discursive procedures include legal deliberations as well as novel participatory approaches (Klinke & Renn, 2002). According to Klüver et al. (2000), in situations of uncertainty, factual knowledge is precisely what scientists cannot provide. Policy makers however, want to know "how safe is safe enough" to lay a solid foundation for their decision-making, but in situations of uncertainty, science cannot factually answer such substantive questions. As the palette of vulnerable assumptions widens and the plurality of perceptions and assessments of these issues increases, new technologies will provoke ambiguous reactions in society.

Three challenges for research and development on the nanoscale

Both policy makers and scientists involved in innovation policy and developments on the nanoscale are confronted with three broad categories of uncertainties: the lack of distinct indicating directions of possible applications (strategic uncertainty), the lack of scientific knowledge (complexity) and the ambiguous reception of new developments in society.

Strategic uncertainty

The early stages of nanotechnology developments leave plenty of room for the curiosity of scientists and engineers to explore the nanoscale. There are three main reasons why technological innovation in the nanodomain has a high goal searching character. Firstly, nano-research seems to be characterised by the implicit, appealing idea that once we gain control over molecular architecture, a lot becomes possible. Secondly, the scope of possible technology paths is increased by the convergence of knowledge and the complementary inputs of diverse disciplines and expertise. On the nanoscale, atoms, electronic bits and genes or DNA, could become interchangeable and thus obscure the boundaries between living creatures (micro-organisms, plants and animals) and non-living electronic devices. At present, research worldwide is taking place that attempts to connect non-living material with living material. Thirdly, the distinction between "knowing" and "creating" is becoming ever more blurred. Traditionally, engineers had the ambition to create usable and relevant applications based on the knowledge delivered by scientists. But on the nanoscale, there is no clear distinction between scientists and engineers, as both try to shape the selective disentanglement of the secrets of the nanoworld.

Complexity

Complexity has to do with what we know and what we do not know, with the completeness of our knowledge and its reliability. Paradoxically, the search for more complete and reliable knowledge about temporal and spatial causes and effect relationships on the nanoscale, relies on the convergence of partial expertise of scientists from different disciplines, with different skills, experiences and intuitions.

Ambiguous receptions

There seems to be a complex interaction between uncertainty on the level of scientific knowledge and uncertainty and ambiguity about the possible societal impacts of nanotechnologies. Scientific lack of knowledge as to the degree of biodegradability of nanocomponents, or the accumulation of toxic components in nanoparticles and infiltration of these particles in humans, to name but a few examples, is inherently linked to the early stage of nanotech development, and as such is neither negative nor positive. More essential is the way certain groups in society, or society as a whole, deals with this kind of uncertainty and understanding underlying purposes and intentions. However, as with all emerging technologies, utopian as well as dystopian visions have sprung up. Optimists foresee a utopian world without environmental degradation, disease or hunger. Pessimists on the other hand, pay exclusive attention to worst-case scenarios, such as the extinction of our own species. Many of these drastic views are based largely on simplified and outdated visions of nanotechnology dominated by self-replicating assemblers and nanomachines. It is therefore necessary to develop ethical views that are more balanced and more informed by what is actually going on in the specific fields of nanotechnology developments (Gordijn, 2005). Presumably, the public in general is more easily persuaded by one sided or oversimplified images than knowledgeable scientists. A well-known example is Michael Crichton's book 'Prey', in which self-replicating machines take over control from humans, or the movie "Fantastic Voyage" (1966), in which a surgical team is miniaturised and injected into the blood of a dying man. Popular talk of such miniature devices, inserted into the human bloodstream to destroy harmful substances, is completely unrealistic at present, but nonetheless evokes the images as presented in the movies. In the book "Engines of Creation: The coming era of nanotechnology", Erik Drexler examines among other things the possibility of "molecular assemblers" and predicts that their existence will completely change the world, as we know it. With "molecular assemblers" we would be able to build anything with perfect precision while at the same time avoiding all pollution. Ultimately, Drexler foresees, they would enable us to colonize the solar system and approach immortality. (4th Nanoforum Report, part 4). It is not known to what degree media coverage shapes people's views on nanotechnology exactly. Whatever their artistic merits, inventive and imaginative plots could make it difficult for laymen to distinguish facts from hypes and science-fiction. However, the media's influence on people's attitudes towards the technology and its applications should not be exaggerated.

Dilemmas

The political system's engagement in technology policy is twofold and is confronted with contradictory demands. On the one hand, governments usually attempt to stimulate scientific and technological research by allowing competitive innovation to take place in a societal climate conducive to such innovation. On the other hand, they are responsible for the adequate regulation of the application of technologies to avoid unintended negative consequences for the citizenry (Klüver et al., 2000). Research and technological developments on the nanoscale still find themselves on a road with many intersections. In the context of swift evolutions and massive uncertainties in research on the nanoscale, scientists and policy makers have to deal with difficulties and are continuously faced with dilemmas. We successively distinguish dilemmas for scientists and technologists, the broad public, and policy makers.

In the nanodomain, a variety of scientific (chemistry, biology and physics) and technological expertise come together where interdisciplinary is not always evident. There is a constant need for more knowledge for future developments and so far this knowledge has not reached a sufficient stage of completeness and certainty. Scientists doing fundamental research generally have no clear views or expectations as to what will be the endpoint of their discoveries. Moreover, technologists are constantly working to expand the boundaries of what is technically possible. Both are faced with two kinds of pressure; on the one hand they are under pressure to deliver and produce results, as globalization spurs ever more competition for rapid technological advancement and scientific knowledge. On the other hand, scientists today are more frequently asked to take time to reflect about their work and its effects on wider society.

Scientific and technological developments will be received in very diverse ways and it is extremely difficult to anticipate public reactions. On account of creativity and inventiveness in research, should emphasis be laid on the differences in values and perspectives? Or should one focus on the quest for consensus and ask how new technologies are to be embedded in a common identity and culture?

Policy makers grapple with other issues as well. Should they focus on a future world full of nano-applications and aim to gain more influence on it? Or should they try as much as possible to monitor the innovations that are put into the market today and thus try to master the unintended (negative) side-effects and steer the developments? This “now” or “later” dilemma, is elaborated in the next section of this paper.

Governing these uncertainties in a Flemish[2] and European context

For some of us, the beauty of the future lies in its unpredictability. However, in our complex, modern day world driven by economic competition, unpredictability is usually taken to be problematic. Governments do all they can to get a grip on the future, by promoting specific innovative developments to help scientists and engineers retain a competitive edge in an unpredictable global market. Moreover, they attempt to monitor current technological developments in order to make corrections to unintended consequences. This is the authorisation or regulation policy. Both innovation policy and regulation policy have developed their own analytical instruments. Technology Foresight (TF) is a toolbox to investigate the future by detecting promising development trajectories (Barré, 2001), whereas Technology Assessment is an analytical tool used to help to understand the likely societal impacts of a new technology. Both TF and TA belong to analytical traditions and support two policy approaches; innovation and regulation respectively.

Flanders is the dynamic, modern, highly industrialised northern region of Belgium, a country squeezed between France, Luxemburg, Germany and The Netherlands. Belgium as such does not have a national innovation policy. As with many other policy domains in this federal state, the Innovation System is decentralised, and there is no hierarchical level between the federal and regional institutional levels, but a horizontal division of competences between the regional governments that cooperate on equal footing. On the TF side there is the Institute for the Promotion of Innovation by Science and Technology in Flanders (IWT) and at the TA-side the Flemish Intitute for Science and Technology Assessment (viWTA).

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[2] For a more detailed overview of innovation policy in Flanders, see Larosse (2004).

Innovation

Currently, Flemish Innovation Policy is characterized as a ‘Third Generation Innovation Policy’, a description which was introduced in the study ‘Innovation Tomorrow’, funded by the European Commission (Lengrand et al., 2002). In this third-generation policy (as opposed to previous generations), innovation is placed on the agenda of every policy domain and no longer limited to the economic realm. This innovation policy wants to contribute to meet other needs in society, e.g. in the areas of education, traffic, healthcare, sustainable development and safety. Innovation is primarily developed interactively, as a systemic activity in which policy instruments are not only directed towards individual organisations (e.g. research and development subsidies, management support) or bilateral relations (e.g. knowledge transfer), but also to the innovation system as a whole (e.g. managing interfaces and organizing learning platforms). From this perspective, it is necessary to identify the relevant stakeholders and to involve them in the innovation process. They share knowledge with each other and learn from experience. Finally, in a third-generation innovation policy, it is important to provide good public information on important waves of innovation and ensure greater public involvement in decision-making (Larosse, 2004; Goorden, 2004).

The centrality of innovation to all policy areas is part of the larger objective outlined by the European Commission to have Europe become ‘the world’s most competitive and dynamic economy’ by the year 2010. This Lisbon Strategy as it is called, was adopted in 2000 as a ten year program in an attempt to deal with low productivity and the stagnation of economic growth, and to ‘solve’ the European Paradox. The paradox is that the European Union plays a leading role in conducting top-level scientific research, but lags behind in converting scientific knowledge into innovative products. For the region of Flanders, the Pact of Vilvoorde (2001) laid the foundations of a new social contract of the 21st century, in line with the Lisbon targets of the EU. In 2002, the Barcelona European Council agreed that research and technological development investment in the EU should be increased with the aim of approaching 3% of GDP by 2010, up from 1.9% in 2000 (COM, 2002). It should however, be noticed that the 3% rule is not to be treated as a goal in itself, but more as an indicator for the transformation to an innovation-friendly Europe with an urgent need to invest in higher border-crossing mobility of skilled people, (risk bearing) capital and network clustering. The Innovation Pact (2003) has specified the commitment of different Flemish innovation actors to the knowledge intensification of the Flemish economy and society. More recently, several platforms (Excellence

Poles) were set up in domains that are important for future development to stimulate research and networking.

Regulation

In Flanders, as in the rest of the European Union, the Precautionary Principle (PP) is strongly embedded in risk assessment policy. This principle was officially recognized in 1992 in order to protect the environment: "Where there are treats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". In more recent times, the PP has been linked to much broader application field (e.g. possible harms to human health, animal health and the environment). In general, the PP calls for preventive actions in all cases of knowledge gaps (e.g. with regard to the toxicity of nanoparticles for the human body. As for nanotechnologies, we wish to emphasize that the European risk regulatory practice is strongly focused on the PP, but this policy has its limitations due to uncertainties inherently linked to the early stages of knowledge about nanotechnologies and their subsequent development. Due to diverse interpretations, the implementation of this principle is a complex issue and falls beyond the scope of this paper

NanoSoc: An experimental approach to midstream modulation in Flanders

Researchers and scientific experts, when making public statements, have the potential to influence both public perceptions and political decision-making. A popular approach to the concept of ‘technological innovation’ gives way to arguments based on a linear model of innovation. In this view, technological innovation is a linear process which runs along consecutive steps, starting with the discovery of new knowledge and ending up with the broad diffusion of an innovative product on the market. In this conceptualisation, scientists and technologists are initiators and guiders of innovation at the same time. The broader public and other users of the scientific and technological achievements have no control or say over the chosen directions. However, this linear model of technological innovation is misguided and over-simplified.

Innovation with new and emerging technologies (such as nanotechnology, or in a broader sense, converging technologies) should be understood as a search process where advancement comes about through variation and selection in different (spontaneous) feedback loops. From this more accurate perspective on innovation, technological innovation represents a process with an open end where the desired characteristics of technological development will become clear step by step.

As we stated before, innovation policy is intended to initiate and stimulate promising R&D trends. By definition, innovation occurs in an early stage, prior to the mass production of relevant applications and can thus be called an 'upstream policy instrument'. Upstream in this sense refers to the early phases of a technology trajectory in the making. Regulation, by contrast, mainly involves legal standards that apply to one or more categories of applications on the market, and therefore implies a certain maturity of the technology. Regulation policy is linked more to the 'downstreaming' of technology paths than innovation policy. The concepts of 'upstream' and 'downstream' are not only useful to discern relevant policies, they can also be used to assess the involvement of relevant stakeholders, such as scientists, technologists, policy makers, the broader public, non-governmental organisations, etc. Erik Fisher (2006) further elaborates on these concepts, as he introduces the idea of midstream modulation of technology trajectories. "Upstream decisions may be characterized as determining *what* research to authorize, midstream decisions as determining *how* to implement R&D agendas, and downstream decisions as determining *whether* to adopt developed technologies. As such, midstream decisions may not seem to carry the same weight or visibility as those entailed during the upstream stage. As do all stages, however, the midstream involves sub-processes that in turn contain nested *what*, *how,* and *whether* decisions".

Our research project, "Nanotechnologies for tomorrow's Society", emphasizes the importance of this sort of midstream modulation, as first and foremost it engages nanoscientists and nanotechnologists. The core objective of the project is to render the promoters of nanotechnologies aware of the underlying ideas, visions, expectations and concerns that guide nanotech research and have them reflect on both likely and alternative developments, through an interactive and iterative social learning process. As they receive inputs from other stakeholders in society, including social scientists, ethicists, interested citizens and consumers, they are invited to refine, alter or rethink existing nanotechnology trajectories. For a more detailed review of this learning process, we refer to the submitted ICNT-paper "Widening the Circle of Nano Research: A Case for Reflective Action Research in Flemish Society" (Michiel Van Oudheusden et al., 2006).

Conclusions

Without a doubt, the vast majority of research, whether in the nanodomain or in other areas, is used beneficially to solve problems and challenges that society as a whole or specific target groups face. There is no rational reason to doubt the good intentions of many researchers and engineers. However, we live in a complex world, where those who initiate innovation and look for solutions, are not solely in control of what will happen when their discoveries and applications are distributed more widely and used to commercial ends.

Both policy makers and scientists involved in innovation policy and developments on the nanoscale are confronted with three broad categories of uncertainties: the lack of distinct indicating directions of possible applications (strategic uncertainty), the lack of scientific knowledge (complexity) and the ambiguous reception of new developments in society. Successful innovation and regulation in the nanodomain depends on dealing adequately with the ambition of cutting through the decision making process in the context of these uncertainties, respectively upstream and downstream at the technologies trajectories. It reflects the dual role of governments; stimulating promising R&D trends without ignoring possible ambiguous feelings towards nanoapplications in current and future society.

In order to deal with these uncertainties as scientists, our project uses Fisher’s concept of midstream modulation. Nanoscientists and nanotechnologists are engaged in a reflexive action approach to technology development in order to render them aware of the underlying ideas, visions, expectations and concerns that guide their research and to have them reflect on both likely and alternative developments. Through an interactive and iterative social learning process, they receive inputs from other stakeholders in society, including social scientists, ethicists, interested citizens and consumers and they are invited to refine, alter or rethink existing and future nanotechnology trajectories.

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References

4th Nanoforum Report. (2005) Part 4: Public Perception of nanotechnology. In: Benefits, Risks, Ethical, Legal and Social Aspects of Nanotechnology. Nanoforum, European Nanotechnology Gateway. [online] www.nanoforum.org [15/09/2006].

Arnall, A.H. (2003) *Future technologies, today's choices*. Greenpeace Environmental Trust, London, United Kingdom.

Barré, R. (2001) Synthesis of Technology foresight. In: Strategic Policy Intelligence: Current Trends, the State of Play and Perspectives, Tübke, A., Ducatel, K., Gavigan, J.P., and P. Moncada-Paternò-Castello (eds.) European Commission, Joint Research Centre, Institute for Prospective Technological Studies (IPTS), Seville, Spain.

Carroll, J.S.(2001) Social Science Research Methods for Assessing Societal Implications of Nanotechnology', in: Societal Implications of Nanoscience and Nanotechnology, Roco M.C. and W.S. Bainbridg (eds), Kluwer Academic Publishers, Dordrecht, The Netherlands.

COM (2002) More Research for Europe. Towards 3% of GDP. Commission of the European Communities. Brussels, Belgium. [Online] http://cordis.europa.eu/era/3percent.htm [12/09/2006] .

EPA (2005) *Nanotechnology White paper. External Draft*. U.S. Environmental Protection Agency (EPA), Washington DC, United States of America.

Fisher, E. Mahajan, R.L, and C. Mitchman (2006) Midstream Modulation of Technology: [Reflexive] Governance from Within*. Forthcoming article*.

Goorden, L. (2004) Innovation Policy and Technology Assessment in Flanders. Flemish Institute for Science and Technology Assessment. [online]

http://www.viwta.be/files/TA2%20Final%20Report(cor%20LG).pdf [03/09/2006].

Gordijn, B. (2005) Nano-ethics: From utopian dreams and apocalyptic nightmares towards a more balanced view*.* Sci Eng Ethics. 11 (4): 521-533.

http://cordis.europa.eu/documents/documentlibrary/GERC021869EN.pdf [05/09/2006].

Klinke, A., and O. Renn (2002) A new approach to risk evaluation and management: risk based, preaution based, and discourse based strategies. Risk Anal. 22 (6): 1071-94.

Klüver, L. et al. (2000) EUROPTA: European Participatory Technology Assessment. The Danish Board of Technology, Copenhagen, Danmark [Online] www.tekno.dk/europta [15/09/2006].

Larosse J. (2004) Towards a 'Third Generation' Innovation Policy in Flanders: Policy Profile of the Flemish Innovation System. IWT-Observatory, Brussels, Belgium.

Lengrand, L. et al. (2002) Innovation Tomorrow. Innovation policy and the regulatory framework: Making innovation an integral part of the broader structural agenda. European Commission, Brussels, Belgium [Online]. http://cordis.europa.eu/innovation-policy/studies/gen_study7.htm#download [12/09/2006].