

## *Nanotechnology's Controversial Role for the South\**

NOELA INVERNIZZI, GUILLERMO FOLADORI,  
DONALD MACLURCAN

*The possibility that nanotechnology will turn into an instrument to aid development or alleviate poverty has been discussed explicitly in academic circles, at meetings held by international bodies, and in non-governmental organisations since 1997. The different positions on the role that it can play in the process reflect particular interpretations on the relationship between science, technology and society. We divide the arguments expressed in this discussion in two broad groups. One can be identified as the instrumental position, which emphasises the technical capacity of nanotechnologies to solve poverty problems and spur development. The other group of arguments can be identified as the contextual position by emphasising the social context wherein technology is produced, used and adapted. We summarise and analyse the main arguments in the debate on nanotechnologies, development and poverty. We consider the most influent opinions from organisations,*

---

\* This is an updated version of "The Role of Nanotechnologies in Development and Poverty Alleviation: A Matter of Controversy", published in *Azojono Journal of Nanotechnology* in 2007.

---

**Noela Invernizzi** is at the Rua Sete de Setembro 357, ap.2, Curitiba, Brazil 80050-100. E-mail: noela@ufpr.br.

**Guillermo Foladori** is at the Sierra Madre Occidental 101-B, Lomas de San Francisco, Zacatecas, ZAC, 98001. E-mail: fola@estudiosdeldesarrollo.net.

**Donald Maclurcan** is at the Institute for Nanoscale Technology, University of Technology, Sydney PO Box 123, Broadway NSW, 2007, Australia. E-mail: Donald.C.Maclurcan@uts.edu.au.

---

*Science, Technology & Society* 13:1 (2008): 123–148

**SAGE Publications** Los Angeles/London/New Delhi/Singapore

**DOI:** 10.1177/097172180701300105

*institutions and meetings, presenting their main ideas in chronological order. The outline covers the period from 1997 to late 2007, and reviews the documents that most directly address the issue. Afterwards, we highlight and analyse the main issues at stake in this controversy.*

## Introduction

THE POSSIBILITY THAT nanotechnology may be able to aid development or alleviate poverty has been discussed in academic circles, at meetings held by international bodies, and in NGOs since 2000.

Over this period several developing countries have been engaging in nanoscience and nanotechnology research programmes. In 2001 the US National Science Foundation claimed that at least thirty countries—both developed and developing—had initiated, or were beginning, national nanotechnology initiatives (Roco 2001). This figure progressed to ‘more than 40’ by 2004 (Huang et al. 2004). According to our research (Maclurcan 2005), this number has grown to sixty-two countries, eighteen of them transitional and nineteen developing, engaging with nanotechnology on a national level. A further sixteen countries demonstrate either individual or group research in nanotechnology, three of which are transitional and twelve developing, including one least developed country. Fourteen countries have expressed interest in engaging in nanotechnology research. Of these, one is transitional and thirteen developing, including three least developed countries. This rapid and broad involvement of developing countries in nanotechnology is often interpreted as a feature of the global character of the nanotechnology revolution (Treder 2004), and as a new trait of global production of science (Hassan, 2005). Different from previous technological revolutions, these characteristics place developing countries (or at least many of them) in a more favourable position to face this revolution and benefit from it. However, this perspective has been a target of criticism in an increasing debate on nanotechnology, poverty and development.

The different positions on the role that nanotechnology can play in alleviating poverty, or in promoting development, reflect particular interpretations on the relationship between science, technology and society. For this reason it is worthy to organise those positions under a theoretical framework. We divide the arguments expressed in this discussion in two broad groups. One can be identified as the *instrumental position*, which

emphasises the technical capacity (and even technical superiority) of nanotechnology to solve poverty problems and spur development. In this sense, this group tends to see technology as neutral artifacts that can be transferred from one context to another unproblematically. In different grades, the arguments in this group reproduce technological determinist approaches, since they stress the beneficial impacts of a given artifact on society. Technologies, in these views, may solve social problems, and social problems are often described as lack of technical capabilities.

The other group of arguments can be identified as the *contextual position* by emphasising the social context wherein technology is produced, used and adapted. Technologies are not simply useful neutral artifacts, but ones that embody social relations, interests, political power, values, etc., that is, socially conditioned artifacts. As such, technologies are a product of particular social structures and tend to reinforce those in which they were created. In this view, factors as profit-driven innovation, intellectual property rights, concentration of innovation in developed countries and social inequality are seen as key factors in the context of development of the nanotechnology trajectory that influence, and even hinder, their use for development and poverty alleviation.

Following this introduction, we summarise and analyse the main arguments in the debate on nanotechnology, development and poverty. We consider the most influent opinions from organisations, institutions and meetings, presenting their main ideas in chronological order. The outline covers the period from mid-2000 to mid-2006, and privileges the documents that most directly address the issue. Afterwards, we highlight and analyse the main issues at stake in this controversy.

### **Review of the Literature: Nanotechnology, Development and the Poor**

In 1997 a document written for the United Nations Industrial Development Organization (UNIDO) concluded that the high cost of nanotechnology-based industries could constitute a barrier for developing countries to 'catch up'; although the outcomes of a nanotechnology revolution, in several areas, could prove of great use for these countries (McKeown et al. 1997). The role of nanotechnologies for the South received increasing attention following a workshop organised by the US National Science Foundation on the 'Societal Implications of Nanoscience and Nanotechnology', that produced a final report in late 2000 (NSF 2001). During

that workshop, the Center for Science Policy and Outcomes (CSPO) presented a paper that drew attention to radical societal transformations that generally accompany rapid technological changes, such as the generation of ‘winners’ and ‘losers’, including the fact that nanotechnology products will be mainly oriented to affluent markets (Crow and Sarewitz 2001; see Appendix for a summary table of the main positions on nanotechnology in chronological order). These led to calls for a real-time technology assessment to assess and monitor these changes (Guston and Sarewitz 2002), thereby incorporating discussions in the technology assessment methodological framework (Schot and Rip 1997).<sup>1</sup>

However, it was not until August 2002, at the World Summit on Sustainable Development in Johannesburg, that the grounds for a debate on nanotechnology, development and poverty were established. At this event, Canadian-based environmentalist organisation the ETC Group called for a moratorium on the development of nanotechnology, alleging scientific indications of potentially severe environmental and human health risks. Some months later, the ETC Group (2003) published a document entitled ‘The Big Down: Atomtech—Technologies Converging at the Nano-scale’, where they elaborated on their arguments first voiced at the Johannesburg summit. Although the purpose of the document is to question the possible impacts of nanoparticles on health and the environment, it explicitly mentions that the problems of poverty, inequality and development are social rather than technical. In this way the ETC group takes theoretical and political distance from the instrumental view that considers poverty and lack of development as a result of technological limitations. In fact, immediately afterwards, in March 2003, an article originating from the University of Toronto Joint Centre for Bioethics (UTJCB) (Mnyusiwalla et al. 2003) mentioned the position of the ETC Group in its first paragraph and went on to defend the instrumental argument, which states that nanotechnologies, if properly developed, could help resolve many problems of poverty and development. The parameters of the debate had been established.

Aside from this incipient confrontation of arguments, it is worth noting that in September 2002 the Asia Pacific Economic Cooperation (APEC) Center for Technology Foresight carried out a workshop to address the challenges of nanotechnology for the APEC developing countries.<sup>2</sup> This meeting was preceded by several position papers in 2001 that were

analysed in a foresight study and used as the basis for the workshop (Tegart 2004). Whilst the papers focused on evaluating research capabilities and obstacles in the region, and assessing potential niche markets to improve competitiveness, the need for a nanotechnology development strategy to solve poverty issues in the region was also discussed (Dayrit and Enriquez 2002). Furthermore, the workshop considered nanotechnology's ability to drive an increasing gap between the rich and the poor, as well as the potential for significant social resistance.

In June 2003 Prince Charles, Prince of Wales, possibly influenced by the ETC Group's document and known to be critical of genetically-modified organisms, alerted the public to possible unintentional consequences of nanoparticles on the environment and human health (Highfield 2003). He supported calls for scientific research into the subject that would be published the following year (RS&RAE 2004). Although on this occasion no reference was made to nanotechnology's effect on developing countries or poverty, it was the 2004 article of Court et al., also of academic origin from the UTJCB, that in its title ('Will Prince Charles Diminish the Opportunities of Developing Countries in Nanotechnology?') related one thing with the other. Only then, in a 2004 article published in the *Independent* newspaper did Prince Charles refer directly to the possibility that the nanotechnology revolution would further widen the gap between rich and poor countries (Prince of Wales 2004)].

The UTJCB continued to reach the academic public with an article in which it presented a map of some governmental nanotechnology initiatives, showing that many developing countries have opted to encourage these technologies (Court et al. 2004). In this article China, South Korea and India were identified as *front-runners*; Thailand, the Philippines, South Africa, Brazil and Chile as *middle ground*; and Argentina and Mexico as *up and comers*. According to the authors, this commitment by Southern governments to encourage nanotechnologies is an indicator of the virtue of these technologies as an instrument for development. In a later article, UTJCB researchers (Salamanca-Buentello et al. 2005) proposed a relationship between the technical advances in nanotechnology and the United Nations Millennium Development Goals (MDG). They suggest that in five of the eight MDGs, nanotechnology may be of great help. Potentially cheaper and more widely available solar energy devices, new methods for water remediation, and rapid cheaper diagnostics for illnesses were seen as a justification of the usefulness of

nanotechnologies for the poor in developing countries. A similar position in terms of its instrumental nature was exposed by the Task Force on Science, Technology and Innovation of the United Nations Millennium Project (Juma and Yee-Cheong 2005). Both institutions registered the most pragmatic and also instrumental position, characterised by identifying a set of technologies considered the most efficient for solving problems of poverty, and promoting their development through research networks and international funds (Singer et al. 2005). While well-intentioned, this position is limited in that it intends to overcome poverty by attacking its most visible causes—a lack of clean drinking water, an absence of cheap, unlimited energy, poor levels of health care, etc.—without really considering the structural reasons for inequality that lead to these situations. From this point of view, social problems are defined in a technical way, and technology is seen as something neutral, which can be applied under any socio-economic context.

In June 2004 forty-three participants from twenty-five countries gathered in the US for the first ‘Inter-governmental Dialogue on Responsible Research and Development of Nanotechnology’ (IDRDN), organised by the US National Science Foundation (NSF 2004). Developing country representation, however, was weak, contributing to 30 per cent of the constituency. Furthermore, in a breakout group at the IDRDN called ‘Nanotechnology and Developing Countries’, only three of the thirteen representatives were from developing countries (Argentina, South Africa and Mexico). Moreover, participants in this group commented that the allocated time for their discussions (less than two hours) was insufficient (Maclurcan 2005). Nevertheless, the meeting raised several challenges that face developing countries seeking to develop nanotechnologies, surrounding infrastructure, human resources and technology transfer. However, owing to the competitive costs, it was also suggested that developing countries could be an attractive place, from a business point of view, to establish new industries. This was possibly the only time during the period under study that this issue of location was explicitly discussed.<sup>3</sup>

Facing the controversies on the possible risks of nanoparticles, the Royal Society and the Royal Academy of Engineering from Great Britain (RS&RAE 2004) published a comprehensive document on nanotechnologies, ‘Nanoscience and Nanotechnologies: Opportunities and Uncertainties’, which includes a series of points concerning the potential effects on developing countries and poverty. The document is clearly

sceptical about the possibilities of solving the problems of underdevelopment and poverty by technical means. It draws attention to patenting, which, although hailed as the driving force of innovation by companies, could become a sticking point for the transfer of technology and even help widen the international technological gap. Despite highlighting the benefits that nanotechnologies could bring to some underdeveloped contexts, the document puts these in second place to social structure, voicing an opinion that is in some way antagonistic to that of the UTJCB and the Task Force on Science, Technology and Innovation of the United Nations Millennium Project.

By the end of 2004 the ETC Group had launched another document, 'Down the Farm', explicitly referring to developing countries and the poor. The document provided crucial focus on several issues relating to nanotechnology's possible effects upon agricultural production and markets. The ETC Group suggested that nanotechnology could lead to substituted products for natural fibres such as cotton and jute, raw materials such as rubber and copper, and beverages such as coffee and tea. They noted that these products today constitute important exports for developing countries, supporting mass employment in these countries. Another key proposition was that nanotechnologies could reorient the use of agricultural land, in some cases creating agro-factories for raw materials and displacing poor peasants. Furthermore, it is believed that nanotechnologies will facilitate a deeper monopolistic control of patents over seeds and other living matter that are the basis for food production and sustaining the livelihood of many. In totality, the document presents a critical outlook for millions of artisans and agricultural workers from developing countries.

With financing from the Rockefeller Foundation, the Meridian Institute, based in Washington, DC, launched a research project focused specifically on nanotechnology and poverty. The starting point was a document that has been in circulation since January 2005: 'Nanotechnology and the Poor: Opportunities and Risks—Closing the Gaps Within and Between Sectors of Society' (Meridian Institute 2005a). This document provided the basis for a public debate, by way of an online questionnaire administered between January and March of that year ((*ibid.* 2005b). The document followed the RS&RAE line of reasoning, claiming that even if the risks of nanotechnologies to health and the environment are adequately identified and administered, there is still the possibility that the

benefits will be restricted to minorities, while the large majority, especially those in developing countries, will end up being excluded. This fear is based on the historical experience of previous technological revolutions that denied their benefits to the poor. The potential for nanotechnology to dramatically reduce the need for many natural raw materials because of the development of substituted alternatives is singled out as one of the most potentially damaging impacts on developing countries, whose exports and labour are concentrated in this sector. The report also highlights that developing countries are in a weaker position to face challenges, such as public debate on new technologies, and the possible need to establish effective regulations. It is also argued that the patenting and licensing systems favour the control of nanotechnologies by developed countries, which can block research aimed at development concerns, leading to a widening of the North–South divide. As a counter-tendency, the report mentions the movement of companies towards ‘pro-poor business’, that is, to developing cheap products for the poorer markets. The report lists several nanotechnological devices that could be exploited for this end, such as water filters and photovoltaic cells.

In February 2005 the International Centre for Science and the UNIDO organised a conference (‘North–South Dialogue on Nanotechnology: Challenges and Opportunities’) specifically focused on the participation of developing countries in nanotechnology (Brahic 2005a, 2005b; Brahic and Dickson 2005). Representatives from governments, academia and industry, as well as international experts took part. Similar to the other international event that was held the year before (IDRDN), there was only a token presence of countries from the South: 13 per cent of the 106 participants from eighteen countries (Maclurcan 2005). There were some appearances by academics and politicians from developing countries, and although they expressed individual opinions, there were some converging positions. In general, they were in favour of the development of nanotechnologies in developing countries if the right areas were selected. Since they foresaw difficulties in putting research (nanoscience) into practice (nanotechnology), they emphasised the need to establish partnerships with industry. They highlighted the importance of ensuring that this new technological revolution did not stimulate greater technological dependence. Of particular interest was a statement by the president of the Third World Academy of Sciences, Hassan (2005). Although he interpreted the successful integration of several countries from the South in

nanoscience and nanotechnology in an optimistic light, he alerted people to the possibility of a growing South–South nano-divide between successful developing countries and the ‘less developed’. However, the conference did not appear to critically engage with the consideration that the ‘for-profit’ industry is guided by market profits, not by solving the problems of poverty. Although it is not possible to judge common opinions on individual reports, the spirit of the meeting as a whole, combined with the lack of critical positions, inclined the conference towards the instrumental perspective. In his article, Hassan (*ibid.*) proposed the establishment of Centres of Excellence in Africa, thereby promoting cutting-edge S&T as necessary for developing countries to succeed. The same idea has been discussed by the leaders of the world’s most industrialised nations (Group of 8) since 2000, with explicit backing for the creation of Centres of Excellence in Africa to encourage the transfer and sharing of S&T between developed and developing countries emerging during its annual summit in Scotland in 2005 (Dickson 2005).

In 2005 the ETC Group released two reports pointing out difficulties for developing countries posed by the nanotechnology revolution. The first report, commenting on proprietary knowledge, shows that nanotechnology’s patenting of basic elements and devices might severely monopolise the possibilities of research and development in the field (ETC Group 2005a). The report highlighted that most patents are already concentrated in the US, Japan, Germany, Canada and France within the hands of large, multinational corporations such as IBM, Micron Technologies, Advanced Micro Devices and Intel. The second report (*ibid.* 2005b), prepared for the South Center, analysed the potential impacts of nanotechnology on markets, particularly those that involve developing countries. Studying the cases of rubber, platinum and copper markets, the document showed that there are nanotechnological procedures that will substantially improve the durability of automobile tyres—the main market for rubber—and that this could significantly reduce the worldwide demand for the product. Carbon nanotubes could become an effective competitor for copper cables, again significantly affecting worldwide demand. Platinum could be replaced by nanotechnology as a catalyst in converters and batteries. These are some examples of the pressure that countries exporting these raw materials will face when they begin to be substituted by nanotechnology products.

The DEMOS Institute, from the UK included nanotechnology in their line of work on public participation in S&T (Wildson and Willis 2004).<sup>4</sup> Leach and Scoones (2006) referred specifically to the use of emerging technologies to alleviate poverty and promote development, emphasising the warning from the document of the RS&RAE (2004): the necessity of ‘upstream’ public engagement. The authors challenged the two main positions regarding the use of S&T to solve poverty issues. They first confronted the argument that S&T, as a driver for economic development and competitiveness, presents benefits that naturally trickle down to the poor, as suggested in reports such as the Task Force on Science, Technology and Innovation, by citing the cases of accelerated technological development and social exclusion witnessed in Bangalore, India. Another perspective they challenged is that adopted by foundations and public–private partnerships, who seek to develop technologies that can be applied to poverty problems globally (a ‘one-size-fits-all’ solution). They argue that this idea of privileging one technology over others has already failed repeatedly by not considering the environmental, social and cultural diversity in which these problems are found, and by closing the door on ‘old’ technologies that can be better adapted to local contexts. In this way, DEMOS reinforced the arguments already made by the ETC Group (2005c) and the Meridian Institute, particularly in the latter’s 2006 report on water. Leach and Scoones proposed a ‘third way’, in which S&T plays an important role, but can only be efficient when adapted to social, cultural and local institutional contexts, and are chosen and designed with the active participation by citizens right from the commencement point.

In a recent report issued by the UNESCO (2006), ‘The Ethics and Politics of Nanotechnology’, inequality was placed as a critical ethical and political question.<sup>5</sup> The report addressed almost all the issues at stake in the debate. It emphasised that the risk of a knowledge gap and inequalities brought by a nanotechnology revolution may be greater *within* nations than between them (the classical North–South gap):

The communication between experts and elites of different countries at the highest levels of research and development has become easier and more common—but the communication between the experts and elites of a nation and the poorer and less well educated has grown less common. (*ibid.*: 15)

The report also problematised the orientation of nanotechnology research to benefit all nations equally. Referring to the arguments of Salamanca-Buentello et al. (2005) on the potential of nanotechnology to accomplish the UN Millennium Development Goals, the report stressed that commercial viability incentives will not be enough to direct nanotechnology research to the need of the poor. In addition, the report warned that excessive patenting in nanotechnology could prevent broad access to research, and it proposed that national governments adopt a policy of open access to publicly-funded materials and research results. Finally, in a context of increasing public scrutiny of science, the need for early public involvement upstream 'into the hearth of scientific work itself' was encouraged.

The year 2007 commenced with increased input into the debates from trade unions, NGOs and civil society organisations, providing new hope for those that consider public participation an important issue in the course nanotechnology will take. By March, a huge confederation, the International Union of Food, Agricultural, Hotel, Restaurant, Catering, Tobacco and Allied Workers' Association (IUF)<sup>6</sup>, with a membership of 365 unions from 122 countries, had raised a public declaration on nanotechnology. Significantly, this world declaration followed the Latin American IUF secretariat declaration, approved in October 2006. In general terms, the declaration called for public debate, warning that products containing nano-components were being launched onto the market before civil society and social movements had a chance to assess their possible implications in economic, environmental and social terms, and their effects on human health. Furthermore, the declaration warned of the need to make sure that debate around a matter that will lead to deep social changes are not be left to the 'experts' (Foladori and Invernizzi 2007).

In May 2007 the Meridian Institute wrote a background paper, 'Nanotechnology, Commodities and Development', for a subsequent workshop held in Rio de Janeiro, Brazil. The paper referred to the challenge of nanotechnologies substituting commodities, and negatively impacting developing countries that rely on the exports of primary materials. Several commodities were analysed and challenges pointed out. On the other hand, the document also highlighted the opportunities that might be derived from the use of nanotechnologies to increase the added value of commodities.

Due to the fact that nanotechnologies are spreading over developing countries, and that different civil society organisations are starting to present more widespread public opinions, an increase in the debate in the near future is expected.

### **Main Ideas and Positions**

The debate on nanotechnology, poverty and development is considerably polarised. On the one hand, nanotechnologies are seen as advanced technologies that could alleviate poverty, or as an opportunity for developing countries to ‘catch up’ with a new technological paradigm, spurring development. On the other hand, its potential to meet these goals is critically scrutinised and often the conclusion is the opposite: they may reinforce inequality.

A set of common features characterises the first, instrumental, position:

1. First, nanotechnology development itself is not problematised. On the contrary, it is taken for granted as inexorable and considered, in a Darwinian way, the most efficient technology. The policy directions are, then, quite obvious: developing countries have to embark on a path of nanotechnology to improve their competitiveness and the living conditions of the people. Developed countries may help in this process, through centres of excellence, research cooperation, etc. Another implication of this evolutionist view is that other/older technological alternatives to solve poverty problems are implicitly seen as superseded.
2. Second, instrumental approaches present poverty problems as lack of access to technologies, without further analysis of poverty’s social causes. Moreover, they tend to homogenise poverty issues and contexts, offering the same ‘one-size-fits-all’ technical solution to very different ecological, social and cultural contexts. In this framework, transference of technology is unproblematic, and the desired beneficial impacts will arise in a mechanical, deterministic way. Moreover, the instrumental perspective sees technology decision making as a matter for experts without any role for the general public.
3. Third, development is frequently equated with growth and competitiveness enhancement, assuming that trickle-down effects will

benefit society as a whole. The extreme instrumental positions substitute technology policy for social policy. However, other perspectives that we have considered instrumental, such as those of the APEC Centre for Technology Foresight and some of the inputs in the two international meetings referred to earlier, do consider some problems and barriers in this process, such as scarce human and financial resources, market entry barriers, expensive intellectual property rights, and consequences of technological change such as unemployment. Nonetheless, the traditional 'linear model of innovation' prevails: innovation will reinforce competitiveness, promoting economic development, and social welfare will emerge as a 'mechanic' outcome.

It is much harder to find such clear, common features within the second group that we called the contextual position. These perspectives share a critical view of the instrumental position, stress the social conditioning of technology, place poverty and development problems in a complex context of socio-economic trends, and ask for a more democratic governance of technology. However, there are significant differences among the positions put together in this group and, consequently, their policy implications vary. In spite of the need for a deeper analysis of such differences, we highlight here the main arguments within the contextual perspective that may contribute to discussions around the ongoing development of nanotechnologies, the way developing countries are engaging in this process, and the potential adverse and beneficial outcomes that can be foreseen. Taking these critical arguments seriously is mandatory for developing countries in order to contextualise nanotechnology policies within economic and social development goals.

One group of arguments looks at developing country engagement with nanotechnology. There is a confluence of opinions stressing the barrier represented by patents, already concentrated around developed countries and multinational corporations. Even basic knowledge is being privatised, and this will be a major obstacle for developing countries to research and adopt nanotechnologies. Other criticisms are directed towards competitiveness enhancement goals when they are considered an expedient means for development and poverty reduction. Several examples are presented about countries that have succeeded in increasing competitiveness in medium- and hi-tech areas, such as India, China and Mexico

without eliminating, and even raising, inequality among their people. This issue is of particular importance for the analysis of nanotechnology policies in developing countries that are mostly focused on competitiveness goals (Foladori 2006; Maclurcan 2005). A third issue regarding developing countries' engagement in nanotechnology is governance. While several developed countries are encouraging different ways of public participation to assess nanotechnology development, this is rare in developing countries. In this respect, it is worth noticing that proposals about nanotechnology governance differ considerably within the contextual perspective.

Another group of arguments surrounds the global impact of nanotechnology's development with respect to developing countries and the poor. It is argued that people in developing countries, and particularly the poor, will, *at least in the short term, be most affected by changes in the division of labour provoked by nanotechnology. The decreasing importance of raw materials due to nanotechnology substitutes will shrink the global demand for traditional export products from developing countries, reducing the country's income, jeopardising industries related to these materials, and decreasing employment opportunities. Other adverse impacts are related to risks associated with nanotechnology. Since developing countries usually have weak regulations, the environment and people are more exposed to any potential risks, and it is even possible that companies exploit this situation when localising plants in those countries.*

*Criticism is also directed towards the very core of nanotechnology's trajectory, which is considered intrinsically limited in its ability to improve the living conditions of the underprivileged. The main assumption of the instrumental position—that nanotechnology products will help the poor—is challenged by arguing that its trajectory is not designed for the poor, but for affluent consumers. Since nanotechnology's development is essentially guided by corporations' search for profits, a majority of innovations are directed to Northern, affluent societies. Products such as personalised medicine, intelligent materials, human enhancement devices, supercomputers and other areas of nanotechnology research will be completely out of the reach of the poor.*

In addition, critics argue that even if some nanotechnology products are technically appropriate for addressing specific problems in developing countries, *it is controversial as to whether products such as water treatment devices, diagnostic kits, and solar energy cells will be accessible to*

the poor. They argue that other efficient and even cheaper technologies already exist to adequately address the same problems, and that even these are often not available to poor people. In addition, even if the technical characteristics of certain nanotechnologies seem adequate for solving specific problems, it remains uncertain as to whether a technology will work well in different contexts. In this sense, critics allude to the risks of privileging a single technological trajectory while other alternative trajectories that could be more context-friendly are discouraged. Such critics recall past experiences with failed universal technological 'solutions' in developing countries. Previous technologies once considered superior, such as the green revolution or genetically-modified crops, have repeatedly failed because they did not adapt well to the local context, or because they contributed to disaggregating communities' social and cultural bonds.

Finally, another kind of argument places nanotechnologies in the context of current socio-economic trends. Nanotechnologies have come into a world in which wealth is highly concentrated and social differences are alarming. Economic forces and enhanced globalisation will probably direct them towards reinforcing these tendencies. Over the past thirty years the world has seen the rapid development of technologies such as microelectronics, information technologies, biotechnologies and telecommunications. But these technological advancements, with applications crossing almost every sector of production, have had questionable impacts on the technology inequality gap. The UNDP's 2005 *Human Development Report* noted that inequality increased over the 1990s on a worldwide basis:

The era of globalization has been marked by dramatic advances in technology, trade and investment—and an impressive increase in prosperity. Gains in human development have been less impressive. Large parts of the developing world are being left behind. Human development gaps between rich and poor countries, already large, are widening. (UNDP 2005: 19)

Confronted with the optimistic instrumental views, it is quite obvious to ask that if inequality increased during the expansion of such powerful technologies over the past decades, why would it be any different for nanotechnologies?

## Appendix

### Summary Table of Main Positions on Nanotechnology and Developing Countries, or Nanotechnology and Poor, in Chronological Order

<i>Ref.</i>	<i>Date</i>	<i>Institution organization author</i>	<i>Arguments</i>
1	2000	CSPO (Center for Science & Policy & Outcomes) (Crow & Sarewitz, 2001).	<ul style="list-style-type: none"> <li>• Radical societal transformations that accompany rapid technological changes produce 'winners' and 'losers'.</li> <li>• Nanotechnology products will be mainly oriented to affluent markets</li> </ul>
2	2002 (August)	ETC gGroup. (2002).	<ul style="list-style-type: none"> <li>• In August 2002, at the World Summit on Sustainable Development in Johannesburg, the ETC gGroup held several workshops calling for a moratorium on the deployment of nano-materials because of the potential risks on health and the environment.</li> </ul>
3	2002 (Setembro September)	APEC Centre for Technology Foresight) (Dayrit & Enriquez, 2002; Tegart, G., 2004).	<ul style="list-style-type: none"> <li>• It is imperative for developing countries to embark inon programmes on nanosciences and nanotechnologies.</li> <li>• It is necessary to select niches and areas for development, taking in account its impact in poverty and competitiveness.</li> </ul>
4	2003 (January)	ETC gGroup. (2003).	<ul style="list-style-type: none"> <li>• wWorkers ..., including those whose skills will no longer be needed ..., will feel the impact first.</li> <li>• A new technology cannot be a “silver bullet” for resolving an old injustice. Hunger, poverty, social disablement and environmental degradation are the consequences of inequitable systems—not of inadequate technologies .</li> </ul>

5	2003 (March) University of Toronto Joint Center for Bioethics. (Mnyusiwalla, et al., 2003).	<ul style="list-style-type: none"> <li>• ‘wWhat at first appears to be very “high-tech” and costly and, therefore, perhaps irrelevant for developing countries, in the end might come to be of most value for those same developing countries. Thus, NTnanotechnology, were it to develop in the way it ought, might ultimately be of most value for the poor and sick in the developing world. At the Johannesburg summit, the main issues for developing countries were poverty reduction, energy, water, health, and biodiversity. NTNanotechnology has the potential to make a positive impact on all of these if its risks either do not materialize or are appropriately managed’.</li> </ul>
6	2003 (June) Prince Charles (Highfield, 2003).	<ul style="list-style-type: none"> <li>• ‘Fears by the Prince of Wales that armies of microscopic robots could turn the face of the planet into an uninhabitable wasteland have prompted the nation’s top scientists and engineers to launch an inquiry’.</li> </ul>
7	2004 (January) University of Toronto Joint Center for Bioethics (Court; et al., 2004).	<ul style="list-style-type: none"> <li>• Several nanotechnologies could alleviate poor living conditions.</li> <li>• DCDeveloping countries are already developing nanotech.</li> <li>• An international network on the assessment of emerging technologies for development should be addressed</li> </ul>
8	2004 (June) International Dialogue on Responsible Research and Development of Nanotechnology- (NSF)	<ul style="list-style-type: none"> <li>• There are infrastructure and social barriers to develop nanotechnologies in developing countries.</li> <li>• Nanotechnologies should be selected focusing the specific context. e.g.for example, in health.</li> <li>• Developing countries are attractive manufacturing centers because of low labour costs, which make them attractive locations for nanotechnology manufacturing.</li> </ul>

(Table 1 contd)

(Table 1 contd)

Summary Table of Main Positions on Nanotechnology and Developing Countries,  
or Nanotechnology and Poor, in Chronological Order (summary table)

<i>Ref.</i>	<i>Date</i>	<i>Institution organization author</i>	<i>Arguments</i>
9	2004 (July)	Prince Charles, 2004.	<ul style="list-style-type: none"><li>• 'But these new applications will inevitably displace existing technologies. Who will lose from that process, and will it widen the existing disparities between rich and poor nations?'</li></ul>
10	2004	RS&RAE (2004)The Royal Society and The Royal Academy of Engineering, 2004.	<ul style="list-style-type: none"><li>• 'N' new technologies creates both "winners" and "losers" ... if a "nanodivide" develops, what can governments do...?'</li><li>• at[A]nalysis ... need ... a case by-case basis, as ... applications come closer to market.</li><li>• [Hh]igh-value ... depends upon exploiting scientific knowledge, the high entry price for new procedures and skills ... is very likely to exacerbate ... divisions between rich and poor.</li><li>• '[E]nthusiasm for developing a "technical fix" ... might ... divert investment from cheaper, more sustainable, or low-technology solutions.</li><li>• [Pp]atents ... too broad ... can work against the public good ... patent offices [should] monitor ... so that any patents ... granted ... support rather than constrain research and innovation.</li></ul>

11	2004 (Noviembre November)	ETC Group, (2004)	<ul style="list-style-type: none"> <li>• Following trends with many previous technologies, nanotechnologies will concentrate even more economic power in the hands of large multinational corporations.</li> <li>• Economies, commerce and modes of life will be deeply affected, especially agricultural production of the South.</li> <li>• Poor nations and those more dependent on agricultural exports will face the main disruptions.</li> <li>• There is likelihood that raw material markets, such as those for certain minerals, textiles and products, including coffee and tea, could be damaged by substitute products that exploit nanotechnology.</li> </ul>
12	2005 (January)	Meridian Institute, (2005a).	<ul style="list-style-type: none"> <li>• The benefits of nanotechnologies could be restricted to minorities, increasing the North–South gap.</li> <li>• Raw material could be reduced, with impacts on exportation and employment reduction in developing countries.</li> <li>• Developing countries are less prepared to face public dialogue and regulations.</li> <li>• Patents could prevent nanotechnologies from being used for development.</li> </ul>
13	2005 (January)	North–South Dialogue on Nanotechnology: Challenges and Opportunities (Brahic, 2005a, 2005b; Brahic &and Dickson, 2005).	<ul style="list-style-type: none"> <li>• Network of leading research and training centres of excellence throughout the developing world</li> <li>• Partnerships between research and industry &amp;, and commercial applications.</li> <li>• Foster business know/-how; Nnanotechnology should not become a new area of technological dependency.</li> <li>• Selecting urgent research areas (e.g.for example, energy, water, health) builds legitimacy for investment and concentrates financial, material an human resources</li> </ul>

(Table 1 *comid*)

(Table 1 contd)

**Summary Table of Main Positions on Nanotechnology and Developing Countries,  
or Nanotechnology and Poor, in Chronological Order (summary table)**

<i>Ref.</i>	<i>Date</i>	<i>Institution organization author</i>	<i>Arguments</i>
14	2005 (February)	Univ. of Toronto, Joint Center for Bioethics (Salamanca-Buentello, <i>et al</i> , 2005).	<ul style="list-style-type: none"><li>• “W”...we have identified and ranked the ten applications of nanotechnology most likely to benefit developing countries [through Delphi method]...we recruited an international panel of 85 experts.... To further assess the impact of nanotechnology ... we have compared the top ten applications with the UN Millennium Development Goals.’ The research identified 5 five out of the 8 eight Millennium Development GoalMDGs that could most likely benefit DC in the 2004–2014 period</li></ul>
15	2005	UN Millennium Project. Task Force on S & T and Innovation (Juma &and Yee-Cheong, 2005)	<ul style="list-style-type: none"><li>• ‘Nanotechnology is likely to be particularly important in the developing world, because it involves little labor, land, or maintenance; it is highly productive and inexpensive; and it requires only modest amounts of materials and energy. Nanotechnology products will be extremely productive, as energy producers, as materials collectors, and as manufacturing equipment.’ (70)</li></ul>

16	2005	ETC gGroup, (2005a,ETC group, 2005b).	<ul style="list-style-type: none"> <li>• It is likely that raw materials will become cheaper in consequence of their being substituted by nanotechnologies and a fall in demand. E.g.For example, there are nanotechnological procedures that will substantially improve the durability of automobile tyres, the main market for rubber, and this could significantly reduce the worldwide demand for the product. Carbon nanotubes could become an effective competitor for copper cables, greatly affecting worldwide demand for this product as well. Platinum could be replaced by nanotechnology as a catalyst in converters, batteries, etc.</li> <li>• 'Without careful planning and evaluation, it is more likely that developing countries dependent on raw materials will be on the receiving end of the potentially adverse repercussions of nanotechnology instead of actively participating in the configuration of the role of nanotechnology in society.'</li> <li>• Patents could become a barrier for developing countries to embody in nanotechnologies.</li> </ul>
17	2006	DEMOS (Leach and Scoones, 2006).	<ul style="list-style-type: none"> <li>• Proposals where poor countries are seen as passive beneficiaries of S&amp;T development and of technological transfer fail or have limited impact.</li> <li>• S&amp;T could only be efficient to overcome poverty if adapted to social, cultural and institutional local contexts, and are chosen and designed through the active participation of its citizens.</li> </ul>

(Table 1 contd)

(Table 1 cont'd)

Summary Table of Main Positions on Nanotechnology and Developing Countries,  
or Nanotechnology and Poor, in Chronological Order (summary table)

Ref.	Date	Institution organization author	Arguments
17	2006	DEMOS (Leach & Scoones, 2006).	<ul style="list-style-type: none"><li>• Proposals where poor countries are seen as passive beneficiaries of S&amp;T development and of technological transfer fail or have limited impact.</li><li>• S&amp;T could only be efficient to overcome poverty if adapted to social, cultural and institutional local contexts, and are chosen and designed through the active participation of its citizens.</li></ul>
18	2006	UNESCO (2006)	<ul style="list-style-type: none"><li>• Risk of a knowledge-gap and inequalities brought about by a nanotechnology revolution may be greater <i>within</i> nations, than between them.</li><li>• Problematises the orientation of nanotechnology research to benefit all nations equally.</li><li>• Commercial viability incentives will not be enough to direct nanotechnology research to the needs of the poor.</li><li>• Excessive patenting in nanotechnology could prevent a broad access to research.</li><li>• Need of a policy of open access to publicly-funded research results and materials.</li><li>• Need for early public involvement upstream.</li></ul>
19	2007	IUF (Foladori & Invernizzi, 2007)	<ul style="list-style-type: none"><li>• Nanotechnologies are reaching the market before civil organisations can assess their potential implications and risks.</li></ul>
20	2007	Meridian Institute (2007)	<ul style="list-style-type: none"><li>• There are both potential concerns and benefits of nanotechnologies for commodity-exporting developing countries.</li></ul>

## NOTES

1. The CSPO was based at Columbia University until 2003 and then shifted to Arizona State University (both in the US).
2. The workshop 'Nanotechnology for the ASEAN Region' was attended by ninety-eight people from nine countries—Australia, Japan, South Korea, Malaysia, Philippines, Singapore, Chinese Taipei, Thailand and Vietnam.
3. The argument is interesting in light of the long-term business projects that appeared later. One example of this is the Silicon Border Development Science Park, located in Mexico near the US border, which is said to be the first Latin American industrial park specialising in nanocomponentes (Presidencia de la República 2006). There is also the potential development of a hi-tech corridor from Houston (Texas) to Monterrey (México) where several nanotechnology industries are already settled (Nanotechnology Inc., Sematech, Motorola, IBM) and a strong research international programme going on (International Center for Nanotechnology and Advanced Materials University of Texas-Austin 2007). Another example is the ambitious 'Nano City' project from Hotmail™ founder Sabeer Bhatia, a city to be built in Haryana, India, at the expense of US\$ 10 billion (Rawat 2006).
4. Some other organisations had spoken out because the recourse of social organisation is the only defence that the civilian population has against the onset of technologies that have largely unforeseeable effects on people because of their novel and disruptive nature. This, for instance, is the viewpoint of Greenpeace (Parr 2005).
5. In a brief session on nanotechnology and ethics organised by UNESCO's COMEST three years previously, this perspective was already clear in Salvarezza's paper (2003), who placed equality as the most relevant ethical question related to nanotechnology from the perspective of developing countries.
6. The IUF is an international federation of trade unions of workers in agriculture and crops, the preparation and processing of food and drinks, hotels, restaurants and catering services, and all phases of the production and processing of tobacco.

## REFERENCES

- Brahic, Catherine (2005a), 'Developing World Needs Nanotech Network', SciDev.Net, 11 February, <http://www.scidev.net/news/index.cfm?fuseaction=printarticle&itemid=1923&language=,1> accessed 27 July 2006.
- (2005a), 'Nanotech Revolution Needs Business Know-how', SciDev.Net, 8 February, <http://www.scidev.net/News/index.cfm?fuseaction=readnews&itemid=1938&language=1>, accessed 27 July 2006.
- Brahic, Catherine and David Dickson (2005), 'Helping the Poor: The Real Challenge of Nanotech', SciDev.Net, 21 February, <http://www.scidev.net/content/editorials/eng/helping-the-poor-the-real-challenge-of-nanotech.cfm>, accessed 27 July 2006.
- Court, Erin, Abdallah S. Daar, E. Martin, T. Acharya and P.A. Singer (2004), 'Will Prince Charles Diminish the Opportunities of Developing Countries in Nanotechnology?' Nanotechweb.org, 28 January, <http://www.nanotechweb.org/articles/society/3/1/1/1>, accessed 27 July 2006.

- Crow, Michael and Daniel Sarewitz (2001). 'Nanotechnology and Societal Transformation'. Paper presented at the National Science and Technology Council Workshop on Societal Implications of Nanoscience and Nanotechnology, 28–29 September, <http://www.aaas.org/spp/rd/ch6.pdf>, retrieved 5 February 2008.
- Dayrit, F.M. and E.P. Enriquez (2002), 'Nanotechnology Issues for Developing Economies', in G. Tegart, ed., *Nanotechnology: The Technology for the 21st Century* (Vol 11, The Full Report). Bangkok: APEC Center for Technology Foresight.
- Dickson, David (2005), 'G8 Leaders Give Indirect Boost for Science in Africa', SciDevNet, 3 September, <http://www.scidev.net/news/index.cfm?fuseaction=printarticle&itemid=2549&language=1>, accessed 1 September 2006.
- ETC Group (2002), 'ETC Group Offers Five Seminars at the Johannesburg Summit'. ETC Group Publications and News, [http://www.etcgroup.org/en/materials/publications.html?pub\\_id=188](http://www.etcgroup.org/en/materials/publications.html?pub_id=188), accessed 23 December 2005.
- (2003), 'The Big Down: Atomtech—Technologies Converging at the Nano-scale', <http://www.etcgroup.org/article.asp?newsid=375>, accessed 27 July 2006.
- (2004), 'Down on the Farm: The Impact of Nano-scale Technologies on Food and Agriculture'. ETC Group, Ottawa.
- (2005a), 'Nanotech's "Second Nature" Patents: Implications for the Global South'. Communiqué No. 87 and 88, March/April and May/June, <http://www.etcgroup.org/documents/Com8788SpecialPNanoMar-Jun05ENG.pdf>, accessed 1 September 2006.
- (2005b), 'The Potential Impacts of Nano-scale Technologies on Commodity Markets: The Implications for Commodity Dependent Developing Countries', South Centre Trade Research Papers, 4, <http://www.southcentre.org/publications/researchpapers/ResearchPapers4.pdf>, accessed 9 June 2006.
- (2005c), 'Nanotecnologia: Os Riscos Da Tecnologia Do Futuro', L&PM, Porto Alegre: L&PM.
- Foladori, Guillermo (2006), 'Nanotechnology in Latin America at a Crossroads', *Nanotechnology Law & Business Journal*, 3(2), pp. 205–16.
- Foladori, G. and N. Invernizzi (2007), 'Agriculture and Food Workers Challenge Nanotechnologies', Rel-UITA, [http://www.rel-uita.org/nanotecnologia/trabajadores\\_cuestionan\\_nano-eng.htm](http://www.rel-uita.org/nanotecnologia/trabajadores_cuestionan_nano-eng.htm), accessed 5 February 2008.
- Guston, David and Daniel Sarewitz (2002), 'Real-time Technology Assessment', *Technology in Society*, 24(1–2), pp. 93–109.
- Hassan, Mohamed (2005), 'Nanotechnology: Small Things and Big Changes in the Developing World', *Science*, 309 (5731), pp. 65–66.
- Highfield, Roger (2003), 'Prince Asks Scientists to Look into "Grey Goo"', *Telegraph*, 5 June, <http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2003/06/05/nano05.xml>, accessed 27 July 2006.
- International Center for Nanotechnology and Advanced Materials University of Texas-Austin (ICNAM) (2007), 'The University of Texas at Austin Joins Forces with Mexican Institutions in Nanotechnology', <http://www.engr.utexas.edu/icnam/>, accessed 5 February 2008.
- Huang, Z., H. Chen, Z.-K. Chen and M.C. Roco (2004), 'International Nanotechnology Development in 2003: Country, Institution, and Technology Field Analysis Based on USPTO Patent Database', *Journal of Nanoparticle Research*, 6, pp. 325–54.

- Juma, Calestous and Lee Yee-Cheong, coords (2005), *Innovation: Applying Knowledge in Development*. London, Sterling, VA: Earthscan, Millennium Project, <http://www.unmillenniumproject.org/documents/Science-complete.pdf>, accessed 11 September 2005.
- Leach, Melissa and Ian Scoones (2006), 'The Slow Race: Making Technology Work for the Poor'. DEMOS, London, <http://www.demos.co.uk/files/The%20Slow%20Race.pdf>, accessed 31 July 2006.
- Maclurcan, Donald C. (2005), 'Nanotechnology and Developing Countries. Part 1: What Possibilities?' AZoNano: Online Journal of Nanotechnology, 1, <http://www.azonano.com/azompdf.asp?ArticleID=1428&heading=Nanotechnology>; and 'Part 2: What Realities?' AZoNano: Online Journal of Nanotechnology, 2, <http://www.azonano.com/azompdf.asp?ArticleID=1429&heading=Nanotechnology>, accessed 2 August 2006.
- McKeown, P.A., J. Corbett, D.C. Cullen and R.W. Whatmore (1997), 'Nanotechnology', in *Emerging Technology Series: New and Advance Materials*, 1. Vienna: UNIDO.
- Meridian Institute (2005a), 'Nanotechnology and the Poor: Opportunities and Risks—Closing the Gaps Within and Between Sectors of Society', January, <http://www.meridian-nano.org/gdnp/NanoandPoor.pdf>, accessed 30 July 2006.
- (2005b), 'Global Dialogue on Nanotechnology and the Poor: Opportunities and Risks (Public Consultation by Internet)', <http://www.nanoandthepoor.org>, accessed 11 September 2005.
- (2006), 'Overview and Comparison of Conventional Water Treatment Technologies and Nano-Based Treatment Technologies', <http://www.merid.org/nano/watertechpaper>, accessed 12 June 2006.
- (2007), 'Nanotechnology, Commodities and Development'. Background Paper for the International Workshop on Nanotechnology, Commodities and Development, 29–31 May, Rio de Janeiro, Brazil.
- Mnyusiwalla, Anisa, Abdallah S. Daar and Peter Singer (2003), "'Mind the Gap": Science and Ethics in Nanotechnology', *Nanotechnology*, 14(3), pp. R9–R13.
- National Science Foundation (NSF) (2001), 'Societal Implications of Nanoscience and Nanotechnology', <http://www.wtec.org/loyola/nano/NSET.Societal.Implications/>, accessed 30 August 2006.
- (2004), 'Inter-governmental Dialogue on Responsible Research and Development of Nanotechnology'. Report, NSF, Virginia, <http://www.nsf.gov/crssprgm/nano/activities/dialog.jsp>, accessed 2 August 2006.
- Parr, Douglas (2005), 'Will Nanotechnology Make the World a Better Place?' *Trends in Biotechnology*, 23(8), pp. 395–98.
- Presidencia de la República (México) (2006), 'Las Buenas Noticias También Son Noticia. Construye México Frontera de Silicón', 12 June, <http://www.presidencia.gob.mx/buscador/index.php?contenido=25519&pagina=1&palabras=Construye+M%E9xico+ frontera+de+silic%C3n>, accessed 2 August 2006.
- Prince of Wales (Prince Charles) (2004), 'An article by HRH The Prince of Wales on Nanotechnology Published in the Independent on Sunday, 11th July, 2004', [http://www.princeofwales.gov.uk/speeches/health\\_11072004.html](http://www.princeofwales.gov.uk/speeches/health_11072004.html), accessed 27 July 2006.

- Rawat, Dinesh Singh (2006), 'Mr Sabeer Bhatia's Nano City, in Haryana', AsiaFront.com: Asian News Network, 20 July, [http://www.asiafront.com/news/134/mr\\_sabeer\\_bhatias\\_nano\\_city\\_in\\_haryana.html](http://www.asiafront.com/news/134/mr_sabeer_bhatias_nano_city_in_haryana.html), accessed 21 August 2006.
- Roco M.C. (2001), 'International Strategy for Nanotechnology Research and Development', *Journal of Nanoparticle Research*, 3(5–6), pp. 353–60.
- Royal Society and Royal Academy of Engineering (RS&RAE) (2004), '*Nanoscience and Nanotechnologies: Opportunities and Uncertainties*'. Policy document 20/04, Royal Society and The Royal Academy of Engineering, London, <http://www.nanotec.org.uk/finalReport.htm>, accessed 27 July 2006
- Salamanca-Buentello, F., D.L. Persad, E.B. Court, D.K. Martin, A.S. Daar and P. Singer (2005), 'Nanotechnology and the Developing World', *PLoS Medicine*, 2(5), <http://medicine.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pmed.0020097>, accessed 27 July 2006.
- Salvareza, Roberto (2003), 'Why is Nanotechnology Important for Developing Countries?' Proceedings of the UNESCO World Commission on the Ethics of Scientific Knowledge and Technology Third Session, Rio de Janeiro, 1–4 December, pp. 133–36.
- Schot, Johan and Arie Rip (1997), 'The Past and Future of Constructive Technology Assessment', *Technological Forecasting and Social Change*, 54(2), pp. 251–68.
- Singer, Peter, Fabio Salamanca-Buentello and Abdallah S. Daar (2005), 'Harnessing Nanotechnology to Improve Global Equity', *Issues in Science and Technology*, <http://www.issues.org/21.4/singer.html>, retrieved 5 February 2008.
- Tegart, Greg (2004), 'Nanotechnology: The Technology for the Twenty-first Century', *Foresight*, 6(6), pp. 364–70.
- Treder, Mike (2004), 'Nanotechnology & Society: Times of Change'. Presentation. São Paulo, Brazil, 18 October, <http://www.crnano.org/Speech%20-%20Times%20of%20Change.ppt>, accessed 12 October 2005.
- UNDP (2005), *Human Development Report, 2005*, [http://hdr.undp.org/reports/global/2005/pdf/HDR05\\_complete.pdf](http://hdr.undp.org/reports/global/2005/pdf/HDR05_complete.pdf), accessed 13 September 2005.
- UNESCO. 'The Ethics and Politics of Nanotechnology', <http://unesdoc.unesco.org/images/0014/001459/145951e.pdf>, accessed 17 August 2006.
- Wildson, J. and R. Willis (2004), *See-through Science: Why Public Engagement Needs to Move Upstream*. London: DEMOS.