The Role of Nanotechnologies in Development and Poverty Alleviation: A Matter of Controversy

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Abstract

Nanotechnologies promise to be the foundation of the next industrial revolution. What role can they play in abating poverty and inequity in the world? This question has been raised, directly or indirectly, by various authors and institutions since the year 2000, when nanotechnology came to be the focus of government research programs, primarily in the developed world but also in countries in the process of development.

In this article we review the positions taken by the principle institutions that addressed that question in the period 2000-2006. We identify two main positions. One gives importance to the technical advantages that nanotechnologies can offer to resolve key development themes, such as potable water, cheap and pollutant-free energy, and the diagnoses and treatment of health matters. This position we call the instrumental position, as it separates technological instruments from the socio-economic context and market pressures that influence nanotechnology development, appropriation and use. The other position, which we call contextual, analyzes nanotechnologies within the framework of social, economic and political forces in which they originate and are developed. Arising out of that context, this second position questions whether new technologies can be leveraged to reduce poverty and inequity in a world that is driven by lucrative interests.

This characterization of the discussion, which at moments could seem rigid, helps to elaborate divergent concepts of the relation between science, technology and society that provide the foundation, legitimacy, or question the agendas of nanoscience and nanotechnology research. It contributes, therefore, to facilitate the political dialogue around said agendas. After reviewing the main positions, the

authors conclude that the contextual position presents strong arguments to be considered in nanotechnology's development.

The literature visited allows arguing that for nanotechnology to play a role in abating poverty and inequality it should be embraced in a range of political policies that go further than just promoting a new technology. Main poverty problems are not due to lack of technology, though a new technology will not, by its own, overcome those development problems.

Introduction

The possibility that nanotechnologies 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 nongovernmental organisations (NGOs) since 2000. Over this period, several developing countries have been engaging in nanoscience and nanotechnology research programs. In 2001 the U.S. National Science Foundation claimed that at least 30 countries –including developed and developing– had initiated, or were beginning national nanotechnology initiatives [1]. This figure progressed to “more than 40”, by 2004 [2]. According to our research [3] this number has grown to 62 countries, 18 of them ‘transitional’ and 19 ‘developing’, engaging with nanotechnology on a national level. A further 16 countries demonstrate either individual or group research in nanotechnology, three of which are ‘transitional’ and 12 ‘developing’, including one least developed country. Fourteen countries have expressed interest in engaging in nanotechnology research. Of these countries, one is ‘transitional’ and 13 ‘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 nanotechnology revolution [4], and as a new trait of global production of science [5]. Differently from previous technological revolutions, these characteristics would place developing countries (or at least many of them) in a more favorable position to face this revolution and benefit from it. However, this perspective has been the target of criticism for not considering the prevailing economic trends that have increased inequality and poverty over the past several decades.

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 organize those positions under a theoretical framework. We divide the arguments expressed in this discussion in two broad groups. One group can be identified as the instrumental position, which emphasizes the technical capacity (and even technical superiority) of nanotechnologies 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 de 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 emphasizing the social context wherein technology is produced, used and adapted. Technologies are not simply useful neutral artifacts but artifacts 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 the social structures 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 could even hinder, their use for development and poverty alleviation.

Following this introduction, we summarize and analyze the main arguments in the debate on nanotechnologies, development and poverty. We consider the most influent opinions from organizations, 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. Afterward, we highlight and analyze the main issues at stake in this controversy.

Nanotechnology, Development and The Poor: The Arguments

Technology as a Subject of Social Assessment

The academic discussion on the societal implications of nanotechnology gained early momentum with a workshop organized by the U.S. National Science Foundation on the 'Societal Implications of Nanoscience and Nanotechnology', with its final report produced in late 2000 [6]. During that workshop, the Center for Science Policy & Outcomes presented a paper drawing 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 [7] (Ref #1, Table 1).

These led to calls for a real time technology assessment to assess and monitor these changes [8], thereby incorporating discussions in the Technology Assessment methodological framework [9, 10]. Any new medicine must pass through varied and expensive tests before coming to market. Should not a highly disruptive technology, as nanotechnology may well be, undergo an evaluation of its social and economic risks and implications before also coming to market? With this argument the authors consider nanotechnologies as a subject of social assessment.

Table 1. Main positions on Nanotechnology and Developing Countries or Nanotec & Poor, in chronological order (summary table).

Ref.	Date	Institution, organization, author	Arguments
1	2000	CSPO (Center for Science & Policy & Outcomes) [7].	• Radical societal transformations that accompany rapid technological changes produce 'winners' and 'losers'. • Nanotechnology products will be mainly oriented to affluent markets
2	08/2002	ETC group [11].	• In August 2002, at the World Summit on Sustainable Development in Johannesburg, ETC group held several workshops calling

			for a moratorium on the deployment of nanomaterials because of the potential risks on health and the environment.
3	09/2002	APEC (Asia Pacific Economic Cooperation) [14, 15].	• It is imperative for developing countries to embark in programs on nanosciences and nanotechnologies. • It is necessary to select niches and areas for development taking in account its impact in poverty and competitiveness.
4	01/2003	ETC group [11].	• "workers … including those whose skills will no longer be needed … will feel the impact first. • 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"
5	03/2003	University of Toronto Joint Center for Bioethics [12].	• "what 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 NT, 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. NT has the potential to make a positive impact on all of these if its risks either do not materialize or are appropriately managed".
6	2003 (June)	Prince Charles [16].	• "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"
7	2004 (January)	University of Toronto Joint Center for Bioethics [18].	• Several nanotechnologies could alleviate poor living conditions. • DC are already developing nanotech. • An international network on the assessment of emerging technologies for development should be addressed.
8	2004 (June)	International Dialogue on Responsible Research and Development of Nanotechnology NSF	• There are infrastructure and social barriers to develop nanotechnologies in developing countries. • Nanotechnologies should be selected focusing the specific context, e.g. in health. • Developing countries are

			attractive manufacturing centers because of low labor costs, which make them attractive locations for nanotechnology manufacturing.
9	07/2004	Prince Charles [19].	• "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?"
10	2004	The Royal Society and The Royal Academy of Engineering [17].	• "new technologies creates both 'winners' and 'losers'… if a 'nanodivide' develops, what can governments do...? • analysis … need … a case by-case basis, as … applications come closer to market. • high-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 • enthusiasm for developing a 'technical fix' … might … divert investment from cheaper, more sustainable, or low-technology solutions • patents … too broad … can

			work against the public good … patent offices [should] monitor … so that any patents … granted … support rather than constrain research and innovation".
11	11/2004	ETC Group [25].	• Following trends with many previous technologies, nanotechnologies will concentrate even more economic power in the hands of large multinational corporations. • Economies, commerce and modes of life will be deeply affected, especially agricultural production of the South. • Poor nations and those more dependent on agricultural exports will face the main disruptions. • 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.

12	01/2005	Meridian Institute [27].	• The benefits of nanotechnologies could be restricted to minorities, increasing the North-South gap. • Raw material could be reduced, with impacts on exportation and employment reduction in developing countries. • Developing countries are less prepared to face public dialogue and regulations. • Patents could prevent nanotechnologies from being used for development.
13	02/2005	North-South Dialogue on Nanotechnology: Challenges and Opportunities [28 – 30].	• Network of leading research and training centres of excellence throughout the developing world • Partnerships between research and industry & commercial applications. • Foster business know/how Nanotechnology should not become a new area of technological dependency. • Selecting urgent research areas (e.g. energy, water, health) builds legitimacy for investment and concentrate financial, material an human resources

14	2005	Univ. of Toronto, Joint Center for Bioethics [20].	• "..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 out of the 8 Millennium Development Goals that could most likely benefit DC in the 2004-2014 period
15	2005	UN Millennium Project. Task Force on S & T and Innovation [21].	• "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"

16	2005	ETC group [32, 33].	• It is likely that raw materials will become cheaper in consequence of their being substituted by nanotechnologies and a fall in demand. E.g. there are nanotechnological procedures that will substantially improve the durability of automobile tires, 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. Platinum could be replaced by nanotechnology as a catalyst in converters, batteries etc. • "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". • Patents could become a barrier for developing countries to embody in nanotechnologies

17	2006	DEMOS [36].	• Proposals where poor countries are seen as passive beneficiaries of S&T development and of technological transfer fail or have limited impact. • S&T could only be efficient to overcome poverty if adapted to social, cultural and institutional local contexts, and are chosen and design through the active participation of its citizens.
18	2006	UNESCO [39].	• Risk of a knowledge-gap and inequalities brought by a nanotechnology revolution may be greater within nations, than between them. • Problematizes the orientation of nanotechnology research to benefit all nations equally. • Commercial viability incentives will not be enough to direct nanotechnology research to the need of the poor. • Excessive patenting in nanotechnology could prevent a broad access to research • Need of a policy of open access to publicly funded research results and materials.

- Need for early public involvement up stream

Is Nanotechnology a Neutral Factor in Socio-Economic Trends?

However, it was not until August 2002, at the World Summit on Sustainable Development in Johannesburg that the grounds for a debate on nanotechnologies, development and poverty were established. At this event, Canadian-based, environmentalist organization ETC Group called for a moratorium on the development of nanotechnology, alleging scientific indications of potentially severe environmental and human health risks [Ref. 2, Table 1].

Some months later, the ETC Group [11] published the document entitled The Big Down: Atomtech – Technologies Converging at the Nano-scale, where they elaborated their arguments first voiced at the Johannesburg Summit [Ref. 4, Table 1]. Although the purpose of the ETC Group 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) [12] [Ref. 5, Table 1] mentions the position of the ETC Group in its first paragraph and goes on to defend the instrumental argument, which states that nanotechnologies, if properly developed, could help to resolve many problems of poverty and development. The parameters of the debate had been established.

It is worth noting that aside from this incipient confrontation of arguments, the Asia Pacific Economic Cooperation (APEC) Center for Technology Foresight carried out a workshop in September 2002 to address the challenges of nanotechnology for the APEC developing countries [Ref. 3, Table 1] [13]. This meeting was preceded by several position papers in 2001 that were analyzed in a foresight study and used as the basis for the workshop [14]. 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 [15]. Furthermore, the possibility of an increasing gap between the rich and the poor as well as potential social resistance to nanotechnology were considered.

Environmental & Health Risks of Nanotechnologies: The Debate

In June 2003, HRH Prince Charles, the Prince of Wales, possibly influenced by the ETC Group's document, and known as a critic of Genetically Modified Organisms, alerted the public to the possible unintentional consequences of nanoparticles on the environment and human health [16] [Ref. 6, Table 1]. The Prince argued that more research should be done on the potential risks of nanotechnologies, endorsing the ongoing investigation from the Royal Society and Royal Academy of Engineering (RS&RAE) that would be published the following year [17].

Although, on this occasion no reference was made concerning the effect on developing countries or poverty, it was the article of Court et al [18] also of academic origin from the UTJCB, which in its title (Will Prince Charles diminish the opportunities of developing countries in nanotechnology?) related one thing with the other [Ref. 7, Table 1]. It was a year later (2004) when, in an article published in The Independent newspaper, Prince Charles referred directly to the possibility that the revolution of nanotechnologies would widen still further the gap between rich and poor countries [19] [Ref. 9, Table 1].

Nanotechnology: The Power to Solve Poverty

The University of Toronto Joint Center for Bioethics (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 [18] [Ref. 7, Table 1]. In this article, China, South Korea and India are identified as front-runners, Thailand, Philippines, South Africa, Brazil and Chile as middle ground, and Argentina and Mexico as up and comers. According to the authors, this will of the governments to encourage nanotechnologies would be an indicator of the virtue of these technologies as an instrument for development.

In a later article the UTJCB researchers [20] [Ref. 14, Table 1] propose a relationship between the technical advances in nanotechnology and the United Nations Millennium Development Goals. They suggest that in five of the eight Development Goals, nanotechnology may be of great help. Potentially cheaper and more widely available solar energy, new methods for water remediation, and rapid and cheaper diagnosis of illnesses were seen as a justification of the usefulness of nanotechnologies to the poor in developing countries.

A similar position, in terms of its instrumental nature, is exposed by the Task Force on Science, Technology and Innovation of the United Nations Millennium Project [21] [Ref. 15, Table 1]. Both institutions register the most pragmatic and also instrumental position, which is characterized by identifying a set of technologies considered the most efficient for solving problems of poverty, and promoting their impulse through research networks and international funds [22].

While good 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 healthcare, 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, whose aims are defined after been produced and that could be applied under any socio-economic context.

In June 2004, forty-three participants from 25 countries gathered in the U.S. for the first Inter-governmental Dialogue on Responsible Research and Development of Nanotechnology (IDRDN), organized by the U.S. National Science Foundation [23]

[Ref. 8, Table 1]. Developing country representation, however, was weak, contributing to 30% of the constituency.

Furthermore, in a breakout group at the IDRDN titled “Nanotechnology and Developing Countries”, only 3 of the 13 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 [3]. Nevertheless, several challenges for developing countries to introduce nanotechnologies were mentioned at this meeting, such as infrastructure services, qualified personnel and transfer of technology. But it was also suggested that developing countries could be an attractive place, from the point of view of the businessman, to set up new industries, owing to the competitive costs. This was possibly the only time during the period under study that this issue of location was explicitly discussed [24].

Socio-Economic Limits For a Win-Win Nanotechnology

Facing the controversies on the possible risks of nanoparticles the Royal Society and The Royal Academy of Engineering from Great Britain [17] [Ref. 10, Table 1], published the research Nanoscience and Nanotechnologies: Opportunities and Uncertainties, which is a comprehensive document on nanotechnologies, and includes a series of points concerning its potential effects on developing countries and poverty. The document is clearly skeptical about the possibilities of solving the problems of underdevelopment and poverty by technical means. It calls attention to patents 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 in one way or another that nanotechnologies could bring to some underdeveloped contexts, the document puts these technologies 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 [25]. The document provided crucial focus on several issues relating to nanotechnology’s possible

effects upon agricultural production and markets [Ref. 11, Table 1]. The ETC Group suggested that nanotechnology could lead to substitute products for natural fibers such as cotton and jute, raw materials such as rubber and copper, or 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 was believed that nanotechnologies will allow a deeper monopolistic control of patents over seeds and other living matter, all necessary for food production. 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 D.C., 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 [26]. This document served as the basis for a public debate, by way of an online questionnaire, between January and March of that year (Global Dialogue on Nanotechnology and the Poor: Opportunities and Risks, Meridian Institute) [27] [Ref. 12, Table 1].

The document follows the line of reasoning of the RS&RAE, claiming that even if the risks of nanotechnologies to health and the environment are adequately identified and administered, there is still the risk that the benefits would be restricted to minorities, while the large majority, especially those in developing countries, would 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 labor 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 establish effective regulations.

It is also argued that the patenting and licensing systems favor 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', i.e. 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.

Problem-Solving: Public Private Partnerships on Nanotechnology

In February 2005, the International Centre for Science and the United Nations Industrial Development Organization organised a conference (North-South Dialogue on Nanotechnology: Challenges and Opportunities) [Ref. 13, Table 1] specifically focused on the participation of developing countries in nanotechnology [28-30]. Representatives from governments, academia, international experts and representatives from industry took part.

Similar to the other international event that was held the year before there was only a token presence of countries from the south: 13% of the one hundred and six participants from eighteen countries [3]. 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 are in favor of the development of nanotechnologies in developing countries if the right areas are selected. They emphasized the need to establish partnerships with industry since they foresaw difficulties in putting research (nanoscience) into practice (nanotechnologies). They were concerned about avoiding this new technological revolution sinking into technological dependence.

Of particular interest was the statement of the president of the Third World Academy of Sciences, Hassan. Although he interpreted the successful integration of several countries from the South in nanosciences and nanotechnologies in an optimistic light, he alerted people to the possibility of a growing South-South nano-divide between those successful developing countries and the less developed [5]. However, the conference had not critically discussed the consideration that 'for-profit' industry is guided by market profits, not by solving the problems of poverty.

Although it is not possible to adjudge common opinions on individual reports, the spirit of the meeting as a whole and the lack of critical positions, incline the conference toward the instrumental perspective. In his paper, Hassan proposes the establishment of Centers of Excellence in Africa, thereby promoting cutting-edge Science & Technology (S&T) as necessary for developing countries to succeed. The same idea has been discussed by the leaders of the world's most industrialized nations (Group of 8) since 2000, and explicitly backed the creation of Centers of Excellence in Africa to encourage the transfer and sharing of Science & Technology between developed and developing countries, during its annual summit in Scotland in 2005 [31].

Market and Development in Nanotechnology

In 2005, the ETC Group released two reports pointing out difficulties for developing countries that the nanotechnology revolution poses [Ref. 16, Table 1]. The first one, commenting on proprietary knowledge, shows that the patenting of nanotechnology basic elements and devices might severely monopolize the possibilities of research and development in the field [32]. The report highlights that most patents are already concentrated in the U.S., Japan, Germany, Canada and France and in the hands of large, multinational corporations such as IBM, Micron Technologies, Advanced Micro Devices and Intel.

The second report [33] prepared for the South Center, analyzes the potential impacts of nanotechnologies on markets, particularly those that involve developing countries. Studying the cases of rubber, platinum and copper markets the document shows that there are nanotechnological procedures that will substantially improve the durability of automobile tires - 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, greatly affecting worldwide demand for this product. 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.

Engaging the public on Nanotechnology

The DEMOS Institute, from the U.K., includes nanotechnologies in their line of work on the public participation on S&T [34, 35]. Leach & Scoones [36] [Ref. 17, Table 1] refers specifically to the use of emerging technologies to alleviate poverty and promote development, emphasizing the warning from the document of RS&RAE [17]: the necessity of upstream public engagement. The authors challenge the two main positions regarding the use of S&T to solve poverty issues. They first confronts S&T as an encouragement to economic development and competitiveness, whose benefits would trickle down to the poor, as highlighted in reports such as 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 challenge 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 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 reinforce arguments also claimed by ETC Group [37] and the Meridian Institute, particularly in their report on water [38].

Leach and Scoones propose a 'third way', in which S&T play 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 the report issued by the United Nations Educational, Scientific and Cultural Oganisation - UNESCO [39] The Ethics and Politics of Nanotechnology, inequality is placed as a critical ethical and political question [Ref. 18, Table 1] [40]. The report addresses almost all the issues at stake in the debate. It emphasizes 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 [39].

The report also problematizes the orientation of nanotechnology research to benefit all nations equally. Referring to the arguments of Salamanca-Buentello et al [20] on the potential of nanotechnology for accomplish the UN Millennium Development Goals, the report stresses that commercial viability incentives will not be enough to direct nanotechnology research to the need of the poor. In addition, the report warns that excessive patenting in nanotechnology could prevent a broad access to research and proposes that national governments adopt a policy of open access to publicly funded research results and materials. Finally, in a context of increasing public scrutiny of science, the need of early public involvement up stream, "into the hearth of scientific work itself" is encouraged.

Main Ideas and Positions on Nanotechnology

The debate on nanotechnologies, poverty and development is considerably polarized. 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, the potential of nanotechnology to meet these goals is critically scrutinized and, often, the conclusion is the opposite: they may reinforce inequality.

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

- First, nanotechnology development itself is not problematized. 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 in nanotechnologies to improve their competitiveness and the living conditions of the people. Developed countries may help in this process, through centers 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.

- Second, instrumental approaches present poverty problems as lack of access to technologies, without further analysis of poverty social causes. Moreover, they tend to homogenize poverty issues and contexts, offering the same 'one best' technical solution to very different ecological, social and cultural contexts. In this framework, transference of technology is unproblematic, and the desired beneficial impacts of them will arise in a mechanical, deterministic way. Moreover, instrumental perspective sees technology as a matter of experts without any role for the people in decision making.

- 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 as well, such those of APEC and the some interventions in the two international meetings referred to above, do consider some problems and barriers in this process, such as scarce human and financial resources, market entry barriers, expensive intellectually property rights and some consequences of technological change such as unemployment. Even though, 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 so 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, so vary their policy implications.

In spite of the need of a deeper analysis of such differences, we will highlight here the main arguments within the contextual perspective that may contribute to discuss 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. Considering these critical arguments seriously is

unavoidable for developing countries in order to contextualize nanotechnology policies within economic and social development goals.

- One group of arguments looks upon developing countries' engagement in nanotechnology. There is a confluence of opinions stressing the barrier represented by patents, already concentrated by developed countries and multinational corporations. Even basic knowledge is being privatized, and this will be a major obstacle for developing countries to research and adopt nanotechnologies. Other critics are directed to competitiveness enhancement goals as a straight way for development and poverty reduction. Several examples are presented about countries that have succeed in increasing competitiveness in medium and high 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, mostly focused in competitiveness goals [3, 41]. 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 to notice that proposals of nanotechnology governance differ considerably within the contextual perspective.

- Another group of arguments is directed to the impacts of nanotechnology global development for developing countries and the poor. It is argued that people in developing countries, and particularly the poor, will be the most hardly affected by changes in division of labor provoked by nanotechnology, at least in the short term. 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, jeopardizing industries related to these materials, and dropping employment opportunities. Other adverse impacts are related to nanoparticles' risks. Since developing countries usually have weak regulations, the environment and people would be more exposed to those risks, and it is even possible that companies explore this situation when localizing plants in the South.

• Criticism is also directed to the very core of nanotechnology trajectory, which is considered intrinsically limited to improve the living conditions of the underprivileged. The main assumption of the instrumental position —that nanotechnology products will help the poor— is put at stake by arguing that nanotechnology trajectory is not designed for the poor, but for affluent consumers. Since this nanotechnology development is essentially guided by the corporations' search for profits, the majority of the innovations are directed to northern, affluent societies. Products such us personalized 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 go further arguing that even if some nanotechnology products are technically appropriate to face specific problems in developing countries, it is a matter of controversy if such products as water treatment devices, diagnostic kits, and solar energy cells will be in fact accessible to the poor. They argue that other efficient and even cheaper technologies exist already to face the same problems and are not available for poor people. In addition, even if technical characteristics of nanotechnologies seem adequate to solve specific problems, it is still not sure that the technology will work well in different contexts. In fact, critics are alerting on the risks of privileging a single technological trajectory while other alternative trajectories that could be more context-friendly are discouraged. In this respect, they recall past experience of failed universal technological solutions in developing countries. Previous technologies once considered superior, such the green revolution or genetically modified crops, have repeatedly failed because didn't adapt well to the local context, or because they contributed to disaggregating communities' social and cultural bonds.

• Finally, another kind of arguments place 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 globalization will probably direct nanotechnologies toward the reinforcement of 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 United Nations Development Program's 2005 Human Development Report notes 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 [42].

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

It is beyond this paper's scope to identify the key foundations for emerging nanotechnology initiatives. Nevertheless, the arguments presented in this paper suggest that for nanotechnology to play a role in abating poverty and inequity, public initiatives in developing countries need to embrace a range of measures that actively promote such ends. These might include research priorities being linked to the most fundamental social needs, truly participative public engagement, policies to compensate potentially affected labour sectors and the development of long-term education strategies. These kinds of measures may assist in reducing nanotechnology's predicted socio-economic disruption.

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American industrial park specializing in nanocomponentes (Presidencia de la República, “Las Buenas Noticias también son Noticia. Construye México frontera de silicón”. June 12, 2006. http://www.presidencia.gob.mx/buscador/index.php?contenido=25519&pagina=1&palabras=Construye+M%E9xico+frontera+de+silic%F3n Retrieved August 2, 2006). There is also the potential development of a high-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 program going on (The International Center for Nanotechnology and Advanced Materials University of Texas-Austin). Another example is the ambitious ‘Nano City’ project from Hotmail™ founder Sabeer Bhatia - a city to be built in Haryana, India, at the expenses of 10 billion dollars (Rawat, Dinesh Singh, “Mr. Sabeer Bhatia's Nano City, in Haryana”. AsiaFront.com - Asian News Network. July 20, 2006. http://www.asiafront.com/news/134/mr_sabeer_bhatias_nano_city_in_haryana.html Retrieved August 21, 2006).

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