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Guillermo Foladori, Noela Invernizzi (Ed.)

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GUILLERMO FOLADORI, NOELA INVERNIZZI (ED.)

Nanotechnologies in Latin America

ReLANS

Red Latinoamericana de Nanotecnología y Sociedad

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Nanotechnology in Latin America

This book analyzes the beginning stages of the development of nanoscience and nanotechnology in Latin American countries. Within are chapters about Argentina, Brazil, Chile, Mexico, the Andes region and Uruguay. Using this regional understanding of development as a foundation, it is possible to reflect on the political, economic, social, legal, ethical and environmental impacts of these emerging technologies within Latin America. Nanotechnology in Latin America also shows the implementation of different science and technology policies throughout the region.

Nanotechnology has reopened the discussion about the role of technology to alleviate poverty and to promote development. In this book, different nanotechnologies are analyzed in the social context from which they are emerging. Factors like industrial production oriented toward profit, intellectual property rights, the amount of innovation in developing countries and social inequities are seen as key challenges that must be addressed if nanotechnology is to assume its potential role as a means to aid development and to alleviate poverty.

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Introduction

Nanotechnology is one of the most far-reaching technological revolutions that human kind has experienced, with the potential to alter the very properties of matter at the molecular level. Since the beginning of the 21st century, public and private investment in nanotechnology research and development (R&D) has increased at a dramatic rate. Today, more than ever, merchandise incorporating nanocomponents are reaching the store shelves. If the estimation is correct, between 2005 and 2015, the market for products containing nanocomponents will grow up to 90 percent. This is possible thanks to the enabling character of this technology which makes it suitable for application in most areas of production. In addition, the multi-functionality of new materials developed from nanotechnology gives to it a disruptive potential in both technological and social terms. Today we are witnessing the development of a new and more powerful technological revolution.

Technology has always been portrayed as the solution to many developmental problems. In the early 1970s, it was estimated that cutting-edge pharmaceuticals were going to eradicate infectious diseases. But, two decades later, old diseases reemerged and new ones became pandemic threats. The most important technological revolutions of our time, the green revolution in agriculture first and the biotechnological second, anticipated the end of malnutrition and famine in the world, but none of those objectives have been achieved. In fact, the opposite occurred, and inequalities in the world widened. Modern satellite communication systems and real-time sources of information could have been mechanisms to improve the dialogue between cultures, religions and countries with different levels of development; yet, wars have proliferated. Automation has decreased the input of manual labor needed in manufacturing, reducing in consequence the number of accidents. However, parallel to this, unemployment has increased, and the intensity of labor has been magnified; as a result, new occupational diseases have emerged. As these examples illustrate, many new technologies have not come hand-in-hand with the reduction of inequality, poverty and suffering in the world. We should ask ourselves then, why would nanotechnologies be different?

Two different arguments have been formulated about the role that nanotechnologies might play in development and poverty. The first argument advocates for the use of nanotechnologies for giving specific solutions to prevailing problems in poor countries, such as: the treatment of polluted and potable water, the development of new sources of energy and the elaboration of new instruments for diagnosis and treatments for diseases. From this perspective, nanotechnology is portrayed as the necessary starting point to support a necessary change in the development process sought by these countries. The second argument argues that these technologies will allow developing countries to "catch up" with their industrialized counterparts. These are the arguments in favor of using nanotechnology for development in most countries in Latin America. The general idea behind the endorsing of this technology is to win niches within the world market. The Brazilian programs, the documents issued by the Mexican government, the Colombian official institution that promotes science and technology (S&T), the Chilean policy briefs related to nanotechnology, and the policies appointed by institutions such as the Organization of American States or Mercosur to support research in the area have as objectives greater competitiveness and the creation of a "knowledge economy." The plan is to change the development platform, from one based on the export of raw materials to one based on the commercialization of advanced technology products, with higher aggregate values.

There has been little coverage in the international media about the development of nanotechnologies in Latin America; even though some countries in the region have allocated large amounts of resources to get on board the nanotechnological wave. Brazil, in 2001, launched a national program to endorse the formation of research networks on nanotechnnology development. This came about shortly after the United States (US) presented its National Nanotechnology Initiative in 2001 with a budget of USD 500-million. In Mexico, dozens of public research centers entered the new century by signing several research agreements with foreign institutions; these institutions also opened graduate courses centered on nanotechnology-related research. In Argentina, since 2005, the Comisión Nacional de Energía Atómica (National Commission of Atomic Energy) was strengthened by directing most of its scarce resources to promote the development of nanotechnology in the nation. COLCIENCIAS, the Colombian institution in charge of S&T, included, in 2004, the area of "advanced materials and nanotechnology" in its research plan. There are other countries with a smaller presence in the area but that have officially allocated some resources to this purpose or have created centers focused on the R&D of nanotechnologies.

Brazil, Argentina and México are the leading countries in nanotechnology R&D in Latin America. In Brazil, there are currently ten scientific research networks working on nanotechnology, all divided according to their areas of interest. Argentina has currently four active networks. In Mexico, the organization is much more decentralized, with the largest university, the Universidad Nacional Autónoma de México (UNAM), concentrating the most the human resources working in the area, with more than 300 researchers. In Colombia there are about 34 research groups undertaking research in nanotechnology.

The role of the private sector in nanotechnology development in these countries and in most of Latin America is still ambiguous. History has shown that the Latin American private sector has not been closely engaged with the R&D of new technologies. The general trend is that companies wait for either the government or public research centers to innovate so they can later make free use of the discoveries. Most scientists see this as the most significant disadvantage, particularly, because in this context, there are very limited possibilities to organize innovation around the development of new merchandise. However, the division between the private and the public sector in Latin America can open a window of opportunity to create large public companies with an interest in applying nanotechnology for the well-being of society. This, of course, would have to include most of the non-profitable areas of nanotechnology development such as: potable water, public health, massive education, popular housing and many others.

It is worth mentioning that the main, if not the only, incentive behind nanotechnology development in Latin America is to encourage an increase in competitiveness. This subject is a matter of concern because the region has clear examples of the consequences of the constant search for an increase in international competitiveness while ignoring social indicators. The case of Mexico is, in this regard, very illustrative. There is neither a mechanical nor a linear correlation between good macroeconomic performance and the improvement of the living conditions of the population. The income concentration and inequality are features of the Latin-American social structure that will not be solved, at least mechanically, by just having a better position in the world market.

Internationally, there is an ongoing debate about the potential health and environmental risks of the use of nanotechnology. In Latin America, the debate is still at its dawn. In 2007, some institutions in Argentina and Brazil have discreetly raised the importance of discussing those issues. It is clear that the subjects should be opened to the scrutiny of the public in a transparent manner as soon as possible. Further, the discussion about the social and ethical implications of the use of this technology is absent in the institutional and academic arena, even though it has been raised by some trade unions. In the region, where inequality is already an important challenge, the changes in the industrial apparatus that nanotechnology will bring are a matter of concern for the working sector and some other social groups. In this context, it is not a surprise to discover the lack of linkage between R&D and the social needs that are widespread throughout Latin America. This link, of course, is absent inside the nanotechnology programs and is completely ignored in the policy rationale behind their implementation.

For these reasons, at the end of 2005, a group of social researchers with an interest on following the development and application of nanotechnology in the region created the Latin American Nanotechnology & Society Network (ReLANS – Red Latinoamericana de Nanotecnología y Sociedad), one of the few networks in the world looking at the social issues related to this revolutionary technology. Shortly after its conception, ReLANS took over the task of developing the first diagnosis of the state of nanotechnology in Latin America. This book is precisely the direct result of such enterprise. For that purpose, members of ReLANS have analyzed the status of nanotechnology of six countries in Latin America: Argentina, Brazil, Chile, Mexico, Uruguay and Venezuela. Most of the authors of this book work at public universities or research centers in those countries where they have managed to collect data from secondary sources and from personal interviews with experts in the area. The book also includes a chapter about the state of nanotechnology in some countries of the Andean Region. This chapter describes the findings of research conducted by an interdisciplinary team between 2005 and 2007 under the coordination of the Institute of Socio-Economic Research (IISEC) of the Catholic University of Bolivia and financed by the International Development Research Centre (IDRC) of Canada. *Nanotechnologies in Latin America* is then intended to provide the groundwork for further studies on the topic.

In the first chapter, the theoretical background and the antecedents with which we examine how this new industry is portrayed by its supporters and those who call for a deeper analysis of its adoption are presented. The chapter on Argentina illustrates the political process that resulted in the creation of the Fundación Argentina de Nanotecnología (the Argentinean Foundation for Nanotechnology). It is indeed a very interesting process which generated several policy shifts and the opening of new research areas within the foundation. The chapter on Brazil examines the points of view of several scientists working in the area of nanotechnology, who are oriented toward the legitimization of the research field by connecting its potential to endorse competitiveness. This chapter also shows the wide array of proposals and the interest of the Brazilian government to extend links to private enterprise by building nanotechnology industrial parks. The next chapter explores the case of Chile, where nanotechnologies are the tools of a government strategy to create a knowledge-based economy. The chapter on Mexico illustrates the growing US influence over nanotechnology development in the country as a result of the lack of a National Initiative. This chapter also identifies the large number of public universities and research centers working on nanotechnology and the different schemes of the bilateral and multilateral agreements signed by the main actors. In the case of Venezuela, the authors analyze the scientific development of nanotechnologies as well as the current state of the research conducted in the nation. The chapter on Uruguay captures the struggle of scientists working in nanotechnology and their efforts to influence the government to recognize it as a strategic area to develop. Within the Andean Region, Colombia emerges as leading country in nanotechnology R&D with an explicit aim to promote these technologies.

The final chapter presents a summary of the findings and gives a general perspective, from the view of ReLANS, about the state and the forces behind nanotechnology development in Latin America. The book offers a complete picture of the leading countries in the continent working in the area. This allows the reader to elaborate a comparative analysis and, at the same time, to understand the specificities of each case.

Guillermo Foladori, Noela Invernizzi

EDGAR ZÁYAGO LAU, MARK RUSHTON

Nanotechnologies for Development in Latin America

Introduction

The "development debate" has existed for decades, with definitions offered, discarded and reformulated. Nonetheless, the wide array of theories and ideas surrounding the development debate, the generation of profit and economic success lay at the core of much institutional development policy. Today, however, most development theorists and practitioners favor a wider-ranging perspective within development studies that includes the environment, gender, labor, culture and various other related aspects of societal change, focusing upon the improvement of the material quality of life for all citizens. This is the window through which the insertion of nanotechnology in the development process of Latin America should be examined.

The current emerging revolution in the nanosciences and the disruptive role of nanotechnologies, potentially represent one of the most profound technological revolutions human kind has ever experienced, with great potential to discover and use new properties from existing materials and of course develop new ones.

In describing this new industry, proponents often cite the potential in particular for the developing countries to embrace nanotechnology as an excellent solution for countless problems, ranging from safe water; energy production; and health care. A core tenet of the nanotech revolution is the potential for significant new economic opportunities, and since developing nations are poor, nanotechnology is thus seen as a tool to "catch up" if only they are able, or assisted, to take advantage of the technology quickly, to jump aboard the ship before it sails out of reach. We would have to ask ourselves if it is possible that a novel technology could solve the problems associated with underdevelopment within a particular socioeconomic context, as the Latin American. Over the past thirty years, the world has seen the rapid development of technology in such fields as microelectronics, information technology, biotechnology and telecommunications; but this technological advancement has not helped to bridge poverty and inequality that are still present in the world. In fact, the United Nations Development Programme (UNDP) has found that despite the technological advancement those problems have deepened:

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. Meanwhile, some of the countries most widely cited as *examples of globalization "success stories" are finding it harder to convert rising prosperity into human development. Progress in reducing child mortality, one of the most basic of human development indicators, is slowing, and the child death gap between rich and poor countries is widening. For all of the highly visible achievements, the reach of globalization and scientific advance falls far short of ending the unnecessary suffering, debilitating diseases and death from preventable illness that blight the lives of the world's poor people (UNDP, 2005, p.19).*

1. Theories of development and nanotechnology in Latin America

Mainstream development theory emerged as an independent branch of economics after the Second World War and with the purpose of explaining the role of the countries that have not reached the levels of industrialization as their counterparts in North America and Europe.

One of the first theoretical frameworks comes from the works of A. Lewis and W. Rostow. With some differences, both authors argue that developing countries have a dual economy, one where a backward economy (based primarily on agriculture and handcrafts) subsists along the side of a modern economy (industrial and capitalist). Lewis argues that development is based on the elimination of the economy based on agriculture and handicrafts; he advocates for the transformation of this economy into a capitalist one (Lewis, 1955). Rostow points out the stages of such transformation which according to him all countries have to go by. The first stage creates the necessary conditions for the take-off; other stage increases the investment rate to the point where it becomes higher than the population grow, then the economy reaches more mature stages where the market is fully developed and where mass consumption takes place (Rostow,1960). Technology as a tool for encouraging industrialization is at the core of this theory.

In Latin America emerges, at the end of the 1940s and at the beginning of the 1950s, a current of economic thought that explains the role of these places in a global context. This school rejects the existing idea that development is just a matter of time and a transition of stages within a natural process of economic activity. The Economic Commission for Latin America and the Caribbean (ECLAC), was were this theory, also known as the structuralist theory of development, emerged. Raul Prebisch was its most important exponent. The economic backwardness or underdevelopment of these countries is not observed as a necessary or normal stage of development but an historical circumstance created by the international economic relations. Other factors that contribute to the exacerbation of this condition are the formation of monopolies created by the central economies and importers of raw materials, and the political relations. Prebisch elaborated a key notion, the center-periphery concept, using the analysis of the deteriorating terms of trade, the result of the quotient between the export price index and the import price index. By the mid 20th century the terms of trade deteriorated for countries that exported raw and basic materials in Latin America due to monopolization and unequal relations of power (with the exception of oil). This had a decidedly negative impact upon the industrialization process in those countries. From this analysis, Prebisch concluded that the problems of underdevelopment in Latin America have structural origins (Prebisch, 1950, 1984). The technological dependency and the role of the dominant elites on impeding any change that would attempt against their interests are central for explaining underdevelopment.

In contrast to these positions, Paul A. Baran (1957) argued that the development of underdevelopment in LDCs was perpetuated by the lack of distribution of power among classes, the control over the economic surplus in all its forms and the inability of LDCs to compete with the advanced capitalist countries. The branches of dependency theory in Latin America, created during the 1970s, took many ideas from the works of Baran. Andre Gunder Frank, T. dos Santos, R. M Marini, V. Bambirra among others, put more emphasis on the class differentiation in developing countries and on the way in which dominant classes associate themselves with the international bourgeoisie with the purpose of exploiting the working class of dependent nations. In this theory, the social relations of production and the class struggle are the key elements to explain dependency, but the idea of developing endogenous technologies is also central to bypass such dependency.

The current neoliberal process of economic growth that prevails in the world was based upon the working ideas of neoclassical economic theory. First Hayek (1944) and latter Friedman (1962, 1980), argued that the liberalization of trade and the integration of national economies are preconditions to encourage economic growth; as long as they are willing and able to successfully compete in that market, under rules of engagement that they have no ability to influence. Within this theory, technology just acts as a commodity and a tool to be purchased in the market to guarantee competitiveness

The idea that development equals economic growth has been contested by proponents of a broader definition of development. Several changes allowed this change, such as the incorporation of women to the wage-labor industry in developed countries and the consequent social movements and their grounds. This illustrated the way in which gender oppression can become a barrier for development, not always considered by formal economics. At the same time, environmental issues became a factor, although they were already in scene since they first appeared in the 1960s questioning the dubious virtues of industrialization and above all, rising awareness about some other angles that were disregarded by conventional economics. In consequence several authors endorsed the broadening of the notion of development beyond economic growth. Within this framework it is believed that increased incomes are a means to achieve development but they will never be the end unto themselves (Sen, 1988; Streeten, 1981). The United Nations Development Programme (UNDP) in its 1990 report created a more comprehensive definition of what human development is: *a process of enlarging people's choices* (UNDP, 1990). Through time the notion of development has gone beyond economic parameters to incorporate issues of environment, gender, ethnicity and livelihoods (Ahooja-Patel, 1982; Chambers and Conway, 1998, 1995 and Chambers, 1987). The Human Development Index (HDI), created by the United Nations Development Programme (UNDP), includes a series of indicators associated with health, housing, education, in addition to the economic factors, for that reason the HDI is widely used as an indicator of development in most nations.

Nevertheless, it is important to point out that the hegemonic idea of what is development is still defined within an economic framework. On the agenda of development agencies at the international level, such as the World Bank and the IMF, economic performance remains the core objective of policy prescriptions. There is recognition of the "incidentals" of development, including impacts of progress on culture and society, the environment, labor and the role of government, but these do not distract from the economic focus that is "development" for these agencies:

The Bank has sharpened its support for the development agenda through a two-pillar strategy for reducing poverty that is based on building the climate for investment, jobs, and sustainable growth and on investing in poor people and empowering them to participate in development (World Bank, 2005).

And, if economic growth still is a determinant factor for development, technology is considered as the main trigger of such economic growth "(i)n a significant sense, then, it can be said that economic development is indistinguishable from the ongoing application of technological knowledge to production" (Cypher & Dietz, 2006, 380).

The notion of technology includes a wide array of elements. We have, on one hand, the material components of the productive processes such as machinery and instruments. On the other, we have several issues to consider like the level of scientific and technological development, the education levels and the way in which a given country or society organizes those factors. That is the reason why technological developments are specific for each country (Cypher & Dietz, 2006, 378).

For neoclassical economics technology are machinery and tools, just commodities and things that are available for the public to generate profits from. In addition, this school argues that the application of a specific technology generates a similar degree of labor productivity in all places. However, this neutral vision of technology, separated from the context in which is applied, is neither what happens in real life nor the position that most authors and institutions believe in. Most economists agree on the idea that the productivity of technology varies under contexts where education, scientific development, regulation, property rights and public policies, are different. Rising a critic to the most pure neoclassical perspective, Cypher & Dietz write:

It is thus not possible for countries to effectively borrow the manifestations of technology, such as physical capital, tools and implements which are so often the focus of the technology transfer literature, and expect to become developed if the human skills, culture, and institutions required to make effective use of this fragment of technology are absent or but poorly formed within the borrowing country (Cypher & Dietz, 2006, 387).

But, beyond the differences between currents, is common to identify in most of them the presumable mechanical relation between the investment of science and technology and development. The example of South Korea for the last two decades of the 20th century has been used to reaffirm that relation. It is not possible to establish that the economic growth or the increase in the Gross Domestic Product (GDP) per capita or even an increase in human development are direct results of allocating more resources into Research and Development (R&D). However, the fact is that the correlation between a higher investment on technology and a higher development seems to be strong and empirically confirmed in most cases.

Despite of having R&D at the center of the development debate, it is not that simple to suggest the path that underdeveloped countries should take to encourage such technological development. There are several questions related to this matter. The agents in charge of financing the process of economic development are a central topic. The origin of the financial resources is another issue because private investment is motivated by the search of profits whereas public investment is motivated by the search of alternatives to improve the living conditions of the population. By the same token, the destination of production (for export or for the internal market) can put conditions over the kind of technological development. It can be also subordinated to different restrictions, rules, competitive standards and even consumer preferences.

Another issue is the capability of a country to innovate which is linked to the learning capability for the appropriation of technological developments from other countries. But also, is related to the capability of a country to create and innovate in order to generate new knowledge that can be eventually transformed into new technologies for production. This problematic raises the importance of analyzing the educational context, the institutions and the promotion of science and technology in a country.

Another issue is the capability that a country has to protect its patents. This is a paramount aspect when try to develop new productive technologies from scratch as the case of the nanotechnologies.

Finally, we have the issue of relative competitiveness. Many authors sustain the idea that developing countries could generate ways to improve their technologies and, in consequence, their rate of economic growth if they could only encourage a rapid process of learning so they can use the technology to catch up. This can be true for certain countries according to their particular context that could allow them to win some spaces in the technological race. The fact, however, is that we live in a world economy and for this reason individual progresses entail the retreat of other countries. The possibility of a win-win relation in a competitive context is non existent. Is natural, under this logic, that policy makers observe the link between science and technology and development, this is the case for nanotechnologies.

In1997 a document written for the United Nations Industrial Development Organization (UNIDO) concluded that the high cost of nanotechnology based industries will constitute a barrier for developing countries to catch up; although the outcomes of the nanotechnology revolution could be of important help for these countries in several areas (McKeown et al, 1997).

More recently, governments, scientists and international organizations have advocated in an optimistic light for the use of the potential capacity of nanotechnology to improve the living conditions of the poor. An example of this is the view of the Task Force on Science, Technology and Innovation of the U.N. Millennium Development Project (Juma & Yee-Cheong, 1995). The Canadian Joint Center for Bioethics ("JCB") also holds the belief that nanotechnology can be used to help achieve five of the eight Millennium Development Goals (Salamanca-Buentello et al., 2005). The organizers of the conference for the North-South Dialogue on Nanotechnology: Challenges and Opportunities, hosted by the United Nations Industrial Development Organization in Trieste, Italy put forward similar ideas (Brahic, 2005a, 2005b; Brahic & Dickson, 2005). This optimistic view is based on the technical potentiality of nanotechnology, particularly for its application to solve the urgent needs of underprivileged populations. This presents a strong argument to encourage nanotechnology R&D in developing countries. But the technical argument is neither the only one nor the most known, to justify it use for development.

The recurrent argument, in the Latin American context, is the increase in competitiveness. Almost all the official documents on nanotechnology issued by the governments of the region have this macro-objective based on the idea that by quickening nanoscience and nanotechnology, there will be an improvement in the competitiveness of the country. This is stated explicitly in the bulletin issued by the Organization of American States (OAS) and repeated in texts made public by the governments of Brazil, Argentina, Colombia, Costa Rica and Mexico. The argument is that nanotechnology can improve competitiveness and thus overcome poverty which is generally associated with stagnant or lower growth economies.

The optimistic vision linked to the potential positive effects of nanotechnologies for development goes together with the implementation of certain policies to encourage science and technology in those countries. The creation of Centers of Excellence in developing countries, portrayed as islands of knowledge and clusters of research infrastructure, are seen as the best path for these countries to achieve the catching up and obtain highest levels of development.[1]

1 See chapter on Chile.

At the dawn of the emergence of a new industrial revolution, the one of nanotechnology, there are several challenges for developing countries. Should these countries actively participate in shaping the trajectory of nanotechnologies? If so Which policies would be the most suitable to obtain what goals? and, How fast these countries should use these technologies? Those are just some of the issues that should be raised and answered.

Unfortunately, most developing countries are getting on board of the bandwagon when it comes to the use of nanotechnologies for development, without discussing the ways and the social and economic implications. In the entire world, but particularly in Latin America, the notion of competitiveness is the one regulating the investment rate in nanotechnology research. To guarantee international competitiveness in the years to come it is necessary to endorse nanotechnology development. But we have to keep in our minds that competitiveness is just one aspect and we are not sure if it is the most important for development.

The main critic of the reductionist notion of development in economic terms came from scholars that refer to the terms of inequity and social differentiation. A country can increase its technological development thus increasing its economic indicators without improving the poverty indicators and/or social inequality. And, however, inequality is a central issue embedded in the modern discourse of democracy and modernity. The case of nanotechnology is illustrative in this regard. The United States of America (US), the country with the highest amounts of resources allocated into the development of nanotechnologies, sets between a fourth and a third of its public investment into R&D of nanotechnology for the military. This stimulates other countries to do the same; the question is if under this trend nanotechnologies would indeed serve to encourage equity or to decrease poverty. Another issue to observe is the fact that most of the patents in nanotechnology are owned by big transnational corporations or US based universities which are also financed by these corporations. We think is valid to ask if under these circumstances nanotechnologies will reduce social inequality and poverty in Latin America and the world.

The environmental critique to the notion of development warned about how conventional economics sees as a positive sign of growth the selling of non-renewable resources, which in material terms means an irreparable lost. It also warned about how environmental pollution represents reposition expenditures having thus a positive connotation. In this regard nanotechnologies have also to provide further answers. Despite there is very little research about the potential effects of nanotechnology to the environment and human health, products containing nanocomponents and production processes using nanotechnology, are rapidly becoming part of market transactions. It is clear that the market and not the reflexive attitude on these new technologies sets the pace for their development.

The humanists critique to economic development asked itself about the limits of technological development. Is technology development a race without ending?

And, if this is true, what is the purpose? Nanotechnologies have to face this issue as well. One of the areas of development within nanotechnology research is the improvement of the human body; the possibility of hybridizing non-biological and biological components is a matter of extensive research. The tranhumanists positions see nanotechnology as the tool to liberate the human from the attachments imposed by nature. These ideas have also to be considered in the development debate.

In the modern world the arena and the agenda to compete in the market are set by the business sector. At the same time, it dictates the rules of science and technology for their applications. This seems to be the case of nanotechnology in Latin America. After the U.S. launched its National Nanotechnology Initiative (NNI) in 2001, many Latin American countries jumped on the bandwagon of competitiveness without creating the subjective social conditions and without considering their particular social context to prepare themselves for a transition into the use of nanotechnology for development.

2. The Current State of Nanotechnology in Latin America

The Ministry of Science & Technology ("MCT") in Brazil held a meeting in 2000 that brought together scientists to prepare an agenda for work on nanosciences and nanotechnology (CNPq, 2000). They prepared a list of the researchers who were involved in the field according to thematic and research centers and proposed a plan of action. In late 2000, it was estimated that there were around 200 researchers working in nanotechnology (Grupo de Articulação, 2001). In 2001, the MCT, through the Brazilian National Research Funding Agency (the Conselho Nacional de Desenvolvimento Científico e Tecnológico or "CNPq") earmarked one million dollars to form cooperative research networks. Four networks were set up: nanostructured materials, nanobiotechnology, molecular nanotechnologies and the interfaces, nanodevices semiconductors and nanostructured materials (CNPq, 2002). In late 2004, a network on Nanotechnology, Society and Environment was created aside from official aids on nanotechnology (Geraque, 2004). Additionally, there are funds from the MCT Millennium Research Programme, which funded four Institutes on Nanotechnology with a total amount of about 9 million dollars. Other funds came from Financiadora de Estudos e Projetos ("FINEP"), the Coordenação de Aperfeiçoamento de Pessoal de nível Superior ("CAPES"), and from the States of the Federation (CAPES, n/d; Presidência da República, 2005). In the year 2004, the Brazilian federal government released its Pluri-Annual Plan (2004-2007), scheduling around $28 million U.S. for the Development of Nanoscience and Nanotechnology ("DNN") program.1 The aim of the program is "to develop new products and processes in nanotechnology with a view to increasing the competitiveness of Brazilian industry" (Gt Nanotecnología, 2003; MCT, 2004a). The government reconsidered the original budget during 2005, increasing federal investment for 2005 and 2006 from the original $19 million to around $30 million (Lemle, 2005).[2]

In 2005, within the DNN, the BrasilNano Network was also set up. This network is one in which companies and research centers are involved in order to quicken the industrial and commercial development of nanotechnologies (MCT, 2004b). Also in 2005 new federal founds allows the creation of 10 nanotechnology research networks. In 2006 substantial funds were oriented to laboratory infrastructure, and a partnership with Argentina was established. IN 2007 a new laboratory for agribusiness was created with an initial spent of 1, 9 million dollars.

México has concluded several agreements and collaborated extensively with national industries and transnational corporations (e.g., HP, Jabil Circuit, Motorota, Hitachi, Agilent Technologies, Calpine, InterGen, Mitsubishi, Monsanto) (Lieffering, 2004). There are several universities and research centers working with nanosciences and nanotechnologies and about twenty research groups. Up until late 2007, there was no federal program to finance, organize or regulate nanotechnology, despite the efforts of some researchers from a variety of institutions to get it under way (Several Authors, 2002; IPICYT, 2005).

Most research groups have bilateral agreements with groups in the United States or Europe, and financing comes from various Mexican and overseas programs. The main agreement is probably the partnership established in 2004 between University of Texas-Austin, International Center for Nanotechnology and Advanced Materials and several centers from the National Council of Science and Technology ("CONACYT") and other universities (Fierro, 2004). According to a study (Lieffering, 2004), the main fields of research in Mexico are the following: integrated circuits, microelectromechanical systems ("MEMS"), semiconductors, sensors and development of new materials. In December 2005, the Committee for Science and Technology of the Senate of the Republic issued a report in favor of the preparation of a National Emergency Program for investment in research and teaching of nanotechnology (Comisión de Ciencia y Tecnología, 2005), nevertheless up to the end of 2007 internal differences did not make this possible.

In **Argentina** in October, 2004, the Economics Minister announced that the government was working on a plan for the development of nanotechnology and digital literacy. He said that had requested the cooperation of the Lucent Bell Company for a support program. The deal would allow the use of the company's Bell Laboratories in New Jersey (Sarmetband, 2005a). Through this agreement, Argentina would avoid having to build a "clean room" immediately, which would, according to the minister, cost 400 million dollars. In addition to the nanotechnology project, they would also seek to increase the sale of computers from eight

2 78 million reales (brazilian money) were, by 2004, about 28 million dollars, but by the end of 2005 the exchange rate rose the amount in dollars to 34 million.

hundred thousand to two million a year (Gobierno Digital, 2004). Five months later, April 2005 saw the formal launch of the Argentinean Nanotechnology Foundation (ANF)[3] with a federal budget of 10 million dollars over the next 5 years and with a tight agreement with Lucent Technologies (Sarmetband, 2005a).

As for the procedure, the Foundation (ANF) was created by presidential decree, and thus did not need the approval of congress. But this procedure sidestepped the Law 25.467 that requires all scientific activities to be coordinated by the National Agency for the Promotion of Scientific, Technological and Productive Innovation (Puig *et al*, 2005a, Sametband, 2005b). Furthermore, the creation of the ANF meant autonomy of decision making in terms of policymaking for science and technology, financing of execution and assessment of results, matters which, according to Law 25.467, should fall to the regulating powers of the Ministry of Education, Science and Technology and Productive Innovation (Puig *et al*, 2005a). The top-down procedure generated an unnecessary bad feeling in the Argentinean scientific community.

The reaction was immediate. The Argentine Physics Association issued a statement condemning the procedure of the creation of the ANF and suggested that it should be adjusted to within the parameters of the Law 25.467 and that it should include all the research groups working in the field (AFA, 2005). In parliament, the Committee on Science and Technology of the House of Representatives made a request for information pertaining to the ongoing scientific research with funds from the U.S. Department of Defense (Puig et al, 2005b) The creation of the ANF in a narrow relationship with Lucent Technologies got to the press and generalized the debate on nanotechnologies and civilian society. The newspaper *Página 12* published articles showing the connection between Argentinean scientific research programs founded by the US DOD, including one on nanotechnology by the NCAE (Ferrari, 2005a, 2005b, 2005c). The National Committee on Ethics in Science and Technology then issued a statement suggesting the regulation of the research and eventually limiting those financed by overseas armed forces (Ferrari, 2005c).

The Argentinean government knew how to convert adversities in benefits. After a succession of changes in the Ministry of Economics, the FAN changed its director and orientation, Lucent Technologies disappeared from the bureau and a new wave started. Four research networks were established and by the end of 2007 a special Ministry of Science and Technology was created and the FAN subsumed to it.

Colombia has a National System of Science and Technology that was set up in 1991. In 2004, the Technical Secretariat (Colciencias) selected eight strategic areas for the development of productivity and competitiveness of the Colombian economy. One of these areas was Advanced Materials and Nanotechnology (Me-

3 National Executive Power Decree number 380/2005.

dina Vázquez, 2005). In July, 2005, the National Council of Nanoscience and Nanotechnology (“CNNN”) was established and assigned to the Colombian section of the Institute of Electrical and Electronics Engineers (“IEEE”). In the following August, the Research and Development Net in Nanotechnoscience was set up, addressing the following areas: autoassembly, replication and nanoscale control; cancer and nanotechnology; nanoelectronics and molecular electronics; nanophotonics, spintronics and nanomaterials; computation nanotechnoscience, quantum and molecular computation; nanorobotics; bionanotechnology; ethical and social implications of nanotechnosciences (CNNN, 2005).

Chile has several research groups involved in nanosciences at a number of universities, including the following: the University of Chile’s Institute of Research and Testing of Materials, the Department of Material Engineering and the Advanced Interdisciplinary Research Center for Material Science; at Federico Santa Maria Technical University, which studies the physics of condensed matter or nanotechnology, and from whence the Millennium Scientific Nucleus project is run with the help of scientists from many universities in the country; the physics department of Catholic University, which receives financial aid from the Andes Foundation; the government funded Fondo Nacional de Innovación y Desarrollo Científico y Tecnológico (“FONDOCYT”); and various international programs (Correia, 2005; Universidad de Chile, 2005).

In August 2004, **Costa Rica** inaugurated the Laboratory for Nanotechnology, Microsensors and Advanced Materials (“LANOTEC”). It is the first of this type in Central America. It will work on research, design and construct of microsensors and carbon nanotubues; it emphasis on this last topic is in agreement with the NASA Goddard Space Flight Centre based in Maryland. The initial $50,000 U.S. funding package includes a “clean room. The construction of LANOTEC and the purchase of the necessary equipment were funded by the Costa Rica – United States of America Foundation for Cooperation, the Costa Rican Ministry of Science and Technology’s ‘incentive fund,’ and the Pro-Cenat Foundation (Vargas, 2004).

In **Venezuela** four institutions concentrate the main bulk of nanotechnology research and there is no official program to encourage nanotechnologies, although some prospective studies indicate this could be the case in the near future.

In Peru there are a few researchers doing nanotechnology in the four major universities of the country. In November 2005, the National Strategic Plan of Science, Technology and Innovation for the Competitiveness and Human Development (PNCTI) 2006-2021 was adopted. The manipulation and design of nanomateriales is one of the issues raised in the Materials Program for development. More recently the National Project of Science and Technology 2006 – 2021 includes nanotechnology as one of the thematic axes for development.

Guatemala is following the steps of Costa Rica. In 2007 launched its *National Program on Science Tecnology and Innovation. Nanotechnology* was considered as of strategic importance and a special unit was to be created in order to encourage its development (Conacyt, 2005). At the beginning of 2007 the second workshop on nanotechnologies was developed in Guatemala City.

In **Ecuador**, the National Policy on Science, Technology and Innovation 2007-2010 was launched by late 2007. No mention to nanotechnology could be find, although this could be Developer within the framework of biotechnology and Information and Communication Technologies, two areas explicitly promoted (SNCyT, 2007). 15 researchers are probably working on nanotechnology.

In **Uruguay**, the dozen of researchers working on nanotechnology are struggling to gain recognition by the government of the importance of its research area, and are having the benefit of being able to participate in the Argentina-Brazil nanotechnology partnership.

Cuba is a special case. With its experience in biotechnology, Cuba could become a big player in naobiotechnology. In 2002, the Cuban Academy of Science and the Ministry of Science, Technology and the Environment voiced the need to incorporate nanotechnology into the offered study programs; this comes at a time when those study programs are under review. The main obstacle is the lack of modern equipment, which explains Cuba's great effort to obtain funding from overseas, participate in international research networks and establish agreements with laboratories in other countries. The strength of Cuba's technological infrastructure is the depth of training and qualifications of the Cuban scientists (del Valle, 2002; Observatorio Cubano de Ciencia y Tecnología, 2002).

The **regional institutions** have recognized nanotechnology as one of the four fields of strategic technological development. The Fourth Regular Meeting of the Inter-American Committee on Science and Technology ("COMCYT") of the Organization of American States ("OAS") was held in Washington, D.C. in April of 2004. It took into account the subject matter covered in four workshops held in different countries over 2003-2004 (OAS, 2004). The workshop held in Ecuador in December 2003 covered hemispheric policies for scientific and technological development in the Americas. It outlined four areas: biotechnology, clean technologies and renewable energy, information networks and technology, and materials and nanotechnology. In the case of materials and nanotechnology, the workshop identified several issues related to urgent needs, including the following: nanobiomaterials, nanotechnology based on optics, electronics, chemicals and environment, the implementation of mechanisms to promote collaborative research, the creation of networks for the development of human resources and training, activities to strengthen the scientific community structurally in these areas; and advisory services for governments. The workshop addressed the need for education, technology transfer and other issues. Surprisingly enough, the workshop produced not a word on nanotechnology regulations or risk assessment (e.g., in the areas of health, environment, and ethics) or socio-economic impacts (OAS-Fundación para la Ciencia y la Tecnología, 2004). This is even more surprising given that the workshops included participation from the U.S. and

Canada, countries that address some of those issues in their own national nanotechnology initiatives.

The Network of Latin American and Caribbean MacroUniversities (Red de Macrouniversidades de América Latina y el Caribe) was created in 2002. The network is extensive and actually covers about thirty public universities from the region. In July 2005, the network created a Multilateral Research Program on Science and Technology in order to produce joint knowledge on various topics. The topics identified as of regional importance included the following: disaster prevention, nanotechnology, energies, biotechnology, environment, education and society (Cruz, 2005). Argentina at the Crossroads

Final remarks

Beyond the differences between countries, the Latin American proposals are characterized by the following common themes: (a) failure to consider the possible socio-economic impacts of the new technologies; (b) failure to conduct studies into the health and environmental risks or the ethical implications associated with nanotechnology; and (c) failure to generate a process for widespread participation in the elaboration of the proposals, thereby reducing discussion to a select group of scientists.[4]

Limited experience with nanotechnology provides no excuse to ignore these issues. The concerns outlined above are common to the introduction of any new technology. It is even more surprising that all of the Latin American initiatives have had the support, direct presence or aid of international specialists—most from the U.S., but also from Europe and Canada—countries where those themes are on the discussion table.

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4 By November 2007 the Ministry of Science & Technology of the Brazilian government launched its Action Plan for 2007-2010, where for the first time issues on ethical and social outcomes of nanotechnology were addressed (see chapter on Brazil). This could be the starting point for a reversal in the trends pointed out.

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Governmental encouragement of nanosciences and nanotechnologies in Argentina

Compared with Brazil or with the United States, where since 2001 governments have been encouraging through public funds the development of nanosciences and nanotechnologies (N&N), governmental support in Argentina is a relatively new phenomenon. In 2004, a policy discussion favoring the development of N&N started to grow, with the exchange of various concerns, doubts and discussions.

On March 18, 2004, throgh the Secretary of Science, Technology and Productive Innovation (SeCyT) from the Ministry of Education, Science and Technology, the First *Workshop on nanosciences and nanotechnologies in Argentina* (SeCyT, 2004) was held. Argentina's N&N status was presented, and the technological challenges for the development of science and technology in those areas were identified. The participants agreed on the need to create a *National Network* to gather all scientists working in the N&N areas, giving birth to working commissions in order to prepare a preliminary document containing ideas and recommendations for a future *Vacancy Area Program* (PAV) to guide where the Argentine State should focus its development efforts.[3]

On November 9, 2004, the National Agency for Scientific and Technological Promotion (ANPCyT) issued a call for project submission, within the PAV framework, for the following areas: forest and farming production; biomedical technologies; coastal areas and seafood resources; nanotechnologies; energy; environmental pollution; aeronautics; state and society. The call for submissions closed on February 15 and resulted in the allocation of 3,553,982 Argentine pesos[4] (23 % of

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2 Physics Bachelor from the Facultad de Ciencias Exactas de la Universidad Nacional de La Plata, Argentina. His research is related to structural and electronical aspects of nanostructured systems and their correlation with chemical-physical features at the Instituto de Investigaciones Fisicoquímicas Teóricas y Aplicadas (INIFTA, FCE-UNLP, CONICET). figueroa@inifta.unlp.edu.ar Member of the Latin American Nanotechnology and Society Network.

3 This first workshop was attended by: the President of the ANPCyT, Dr. Lino Barañao and representatives from various research centers: INQUIMAE-FCEYN-UBA, Dr. Sara Bilmes and Dr. Ernesto Calvo; DF-FCEyN–UBA, Dr. Andrea Bragas; CONICET–CITEFA, Dr. Noemí Walsö De Reca; CITEI, INTI, Eng. Liliana Fraigi; FI–UBA, Dr. Stella Duhalde; CNEA-CAC, Dr. Ana Llois; INIFTA–La Plata, Dr. Roberto Salvarezza; INTEC, Sta. Fe, Dr. Roberto Koropecki; Universidad Nacional de Entre Ríos, Dr. Fabio Guarnieri; Universidad de Río Cuarto, Dr. Diego Acevedo; FAMAF–Córdoba, Dr. Horacio Pastawski; CAB–CNEA, Dr Roberto Zysler; CAB-CNEA, Dr. Hernán Pastoriza and Dr. Francisco de la Cruz.

the total funds allocated) toward four N&N projects, all of the type II vacancy area[5] (ANPCyT, 2004).

Financed projects were as follows: “Network laboratory for designing, simulating and manufacturing nano- and micro-appliances, prototypes and samples,” with $898,769 (UN Entre Ríos, CNEA-CAC, CONICET and UNL, CNEA-CAB, UN del Nordeste);[6] “Bionanostructure self-organization for molecular information transmission on neurobiology and biological processes” with $893,694 (UN of Córdoba and CIQUIBIC, UN of San Luis, UN of Tucumán-CONICET); “Nanotechnology and nanoscience Argentine network: nanosystems and nanostructured materials (MaN),” with $899,959 (CNEA-CAB, CNEA-CAB, UBA, CONICET, UN of San Luis); and “Interface, ultramolecular, and molecular nanotechnology and nanoscience Argentine network,” with $861,560 (UN of Río Cuarto, UN of Córdoba, CNEA-CAC, CONICET-UNLP, UBA, UN of San Luis, CNEA-CAB). These four projects are the four N&N networks publicly financed and recognized through mid-2007 in Argentina. The networks include about two-hundred researchers (Balseiro, 2007).

On November 5, 2004, the then-Minister of Economy and National Production, Roberto Lavagna, speaking at the 40th IDEA Annual Colloquy, said: “a month ago we started working on a relevant program in Argentina concerning nanotechnology,” while at the same time, he specified that the multinational company “Lucent Technology” enthusiastically accepted the invitation from the Ministry of Economy and National Production to initiate a nanotechnology development and support program in Argentina,” highlighting that the “nanotechnology main areas are: medicine, optics, car industry, capital goods, communications and computer science”. He remarked that “they represent future stakes that shouldn’t be left aside by our country,” pointing out, as for the program content, that “every clean room intended to produce nanotechnology costs 400 million dollars.”[7] He announced that “with this agreement, Lucent clean rooms will be used” (Lavagna, 2004a).

4 1U$s=3 Argentine Pesos.

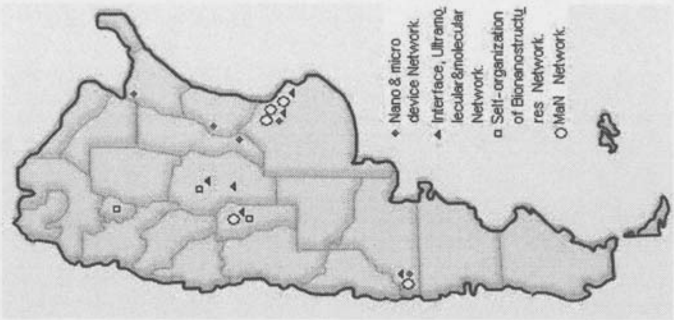
5 Type II PAV: network consisting of at least three research group nodes, belonging to one or more beneficiary institutions, the units of which are located in three different provinces.

6 UN (Universidad Nacional=National University); UNL (Universidad Nacional del Litoral); CNEA (Comisión Nacional de Energía Atómica=Atomic Energy National Committee); CAC (Centro Atómico Constituyentes); CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas=National Council of Technical and Scientific Investigations); CIQUIBIC (Centro de Investigaciones en Química Biológica de Córdoba-Biological Chemistry Research Center of Cordoba); UNLP (Universidad Nacional de La Plata-National University of La Plata); UBA (Universidad de Buenos Aires=University of Buenos Aires); CAB (Centro Atómico Bariloche=Bariloche Atomic Center).

7 Class 1 clean rooms (they are the best, with less than 1 particle over 0.5 micron per air cubic foot) cost amount to around U$S 5000 for each 0.0929 m2. Budget provided by the Minister of Economy is equivalent to a 7432 m2 room of such quality, which represents almost the double of size being used by most companies devoted to microelectronic production.

PAV 2004. Nanotechnology. Financed Networks.

Network laboratory for designing, simulating and manufacturing nano- and micro-appliances, prototypes and samples.	UN of Entre Ríos. CNEA-CAC. CNEA-CAB. CONICET-UNL. UN of Nordeste.	Grant Total Amount: $ 898709
Bionanostructure self-organization for transmission of biological process and neurobiology molecular information.	UN of Córdoba-CIQUIBIC. UN of San Luis. UN of Tucumán-CONICET	Grant Total Amount: $ 893694
Nanotechnology and Nanoscience Argentine Network: nanosystems and nanostructured materials (MaN).	CNEA-CAB. CNEA-CAC. UBA. CONICET. UN of San Luis.	Grant Total Amount: $ 899959
Interface, Ultramolecular, and molecular Nanotechnology and Nanoscience Argentine Network.	UN of Río Cuarto. UN of Córdoba. CNEA-CAC. CNEA-CAB. UNLP-CONICET. UBA. UN of San Luis.	Grant Total Amount: $ 861580



Note: during 2006 and 2007, more groups joined the already-existing networks, including other knowledge branches, such as the Drug Targeting Strategy Design Laboratory of the Universidad de Quilmes, in Buenos Aires, which performs research on nanomedicine; therefore, the chart may not be up-to-date.

On November 25 and 26, 2004, the SeCyT, with representatives of the European Union, carried out a meeting in Buenos Aires to promote national capacities in the area of N&N, forming links to research programs and European networks.[8]The same year, in December, the Minister told the press that "as regards science and technology, money means just a part," saying that a program intended for N&N development had just been launched. Faced with the question of why a strong budget increase does not assure a greater growth in matters of science and technology, Lavagna said that "it may be just restricted to the salary payment. Or, as happened to me the other day during a meeting with a group of scientists, someone, very proud, pointed out that they were manufacturing... aspirin. ¿Can you see the point? It shouldn´t be so. That is a misused public fund." He elaborated on his position in the sense that "they are programs which require political decisions and coordination rather than a lot of money. As regards nanotechnology, the initial supply included in the budget amounts to around two-million pesos. Nevertheless, with two million pesos we are summoning the attendance of one of the most important companies worldwide on this matter" (Lavagna, 2004b).

Several people questioned the Minister's statements:[9] "Lucent represents everything except the best example of a successful company. Its history, linked to that of Bell laboratories, is full of unlawful acts ? connected, for example, to Enron fraud, collapses and errors. To become convinced, you may read the book by Lisa Endlich *Optical Illusions: Lucent and the Crash of Telecom*". Or just read any of those "articles shown in a Google search if you write, for example, two magically connected words, such as «Lucent» and «troubles»."

The State, through Decree Nº 380/2005, signed by President Néstor Kirchner, together with Ministers Alberto A. Fernández, Roberto Lavagna and Daniel Filmus, quoted in the Official Bulletin Nº 30.643 as of April 29, 2005, authorized the "Ministry of Economy and Production to create the Argentine Nanotechnology Foundation (FAN)" (sec. 1), where "the National State within the Foundation mentioned under Section 1o of this Decree will be represented by the Ministry of Economy and Production" (sec. 2), as long as this Ministry is authorized to appoint the representatives as stipulated under FAN statute (sec. 3). A $12,000 amount (sec. 4) was made available to implement those acts, to achieve FAN´s goals (sec. 5). According to sec. 6 "Be it communicated, published, and delivered to the Dirección Nacional del Registro Oficial (National Department of the Official Registry) and be it filed" (FAN, 2005).

The Decree creating the FAN, with the statements of Minister Lavagna, attracted the critical attention of different sectors involved. In a report from the board of directors of the Asociación Física Argentina (AFA, 2005) it was said that,

8 See http://www.secyt.gov.ar/coopinter_archivos/multilateral/ue_talller_nanotecno.htm.

9 Dr. F. Schaposnik has written about Lavagna´s statements and the relevance of such company, as well as about the disciplinary field lobby (http://www.fschaposnik.com.ar, Postgrad Course "*Introduction to Scientific Knowledge Methods*", 1st. Semester, 2005). In such course, the book by Endlich, Lisa (2004). *Optical Illusions : Lucent and the Crash of Telecom* is quoted. New York: Simon and Schuster.

It is unclear if the procedures used to create FAN -mechanisms specified by accrediting systems and project evaluation from the national scientific-technological systems- have been met, as regulated by Law Nº 25.467. We consider that this behavior is not consistent with the required transparency and seriousness which must guarantee an initiative that, due to its nature, raises the future expectations of our society which, obviously, is hoping for development and tired of frustrations.

In addition to legal-technical statements, it was said that:

The nano- and microscience and technology world is quite large; Argentina has researchers examining research lines ....[to decide] which are going to be the most appropriate niches to be developed (AFA, 2005).

Some comments concerning the Decree were published by the press, all of which agreed that it was a measure to strengthen and support the industrial sector. In the newspaper *Clarín*, April 28, under the headline *Economy swaps debts against industrial investment*, it is reported that "Minister Roberto Lavagna announced yesterday a package of measures to encourage industry investments," which included those measures implemented through Decree 380 (Clarín, 2005). *La Nación*, reported that, "additionally, as from Decree 380, the creation of a foundation to support projects for nanotechnology development was approved" (La Nación, 2005a). In *El Comercio* it was reported that "10 million dollars are allocated to a dubious foundation" (El Comercio, 2005). Infobae reported that "Lavagna announced initiatives for the industrial sector," restricted to Decree 380 within this series of measures (Infobae, 2005).

From the Chamber of Representatives of the Nation there came voices opposing the implementation of Decree 380. Then-Representative for Santa Fe, Lilia Puig de Stubrin, headed the dissenting voices and submitted a project requesting, on May 13, 2005, a report to the National Executive Power (PEN) to clarify certain items concerning the FAN's creation (Puig de Stubrin, et al. 2005a and 2005b). The request is based, among others, on the following:

Some hours before Resolution 380/2005, authorizing the Ministry of Economy to create and integrate the Argentine Nanotechnology Foundation, was published in the Official Bulletin, it was ratified that its creation would be supported by an agreement with the Lucent-Bell company, and the creation of a board of directors presided over by the Secretary of Industry and made up of CNEA representatives and of the company, which would make available to Argentine researchers and staff training, design testing and other activities connected with its facilities. This agreement would have been managed by a researcher appointed by the Ministry of Economy, presumably Dr. Smith. Among the Decree´s provisions, Annex I indicates that the National State pledges itself to supply ten-million dollars during the first five years, in accordance with a Statement of Work which will be stipulated by an Administration Council which will run and manage the Foundation (Puig de Stubrin, et al, 2005a).

Concerns were also expressed regarding:

the unlawful creation – according to a regulatory ruling on the production innovation, technology and science activities and through the Ministry of Economy and Production, without the intervention of the Secretary of Science and Technology and Production Innovation of the Ministry of Education, Science and Technology of the Nation- of the Foundation with funds from the National State, without the criteria being known concerning its technical feasibility, from the expert body on the matter" (Puig de Stubrin, et al, 2005b).

The first three items (out of eleven) involved in the application submitted to PEN must be given special notice, since:

• they called into question whether "all the provisions established by Law 25.467 for the implementation of Dec. 280/2005 had been met, with regard to the scientific policy objectives";

• they require awareness of "all the proceedings that gave rise to the creation of the Argentine Nanotechnology Foundation";

• they ask whether "in determining the support to be given by the State toward the construction of the FAN, there had been a guarantee of equal opportunity for country's scientific-technological establishment, through a process of public tender for the financing of projects that had been evaluated and approved by the peer appraisers";

• and, with regard to the statements of the Minister of Economy, that the explanation of the primary criteria for the selection of scientists and information regarding their previous links with Lucent Bell is requested.

On September 25, 2005, in *Página 12*, Andrea Ferrari published an article with the heading *The sea battle of the Argentine scientists (the American Navy finances research projects in our country)* (Ferrari, 2005a). This article gave rise to angry public controversy, apart from a "discussion on the difficult relationship between science and military power". Therein it was stated that among the three projects involved, there was at least one related to nanotechnology. Therefore, from another perspective, that of ethics, this branch of knowledge took on connotations of a public and conflicting nature. "Under the title of "Nanomaterials for Sensors", published on the official webpage of the U.S. Office of Naval Research (ONR), a projeectd is mentioned which was initiated in 2004 with the NRL (National Research Laboratories) and by the Argentinean Balseiro Institute, which is funded by the National Atomic Energy Commission (CNEA)". This places the initiative into question as to what ends are served by scientific research within a peripheral country. The news emerged from the report requested by Representative Puig de Stubrin. Expressions of protest soon came against a disengaged scientific activity that restricts itself to just the scarce project financed for basic research (*Página 12*, 2005; Foladori, 2006).[10]

10 Estos hechos han tenido otras consecuencias en el CAB; para más detalles véase http://www.rionegro.com.ar/arch200603/23/m23j77.php , http://www.rionegro.com.ar/arch200603/24/r24j10.php .

In 2005, the Ethical National Committee on Science and Technology (CECTE), in reply to the Argentine Physics Association which asked for the oversight of "CECTE concerning the ethical aspects involved in the sanction of Decree 380/2005, relative to micro- and nanotechnology development and application," stated that:

Any decree allocating relevant amounts of money to a foundation created with no requirement to comply with the legal system would conflict with the structure so carefully designed by the Congress of the Argentine Nation [Law 25.467, Innovation, Technology and Science Framework Law] is an obvious violation of the equality principle, so highly valued ethically and legally (CECTE, 2005a).

Accordingly, the CECTE "recommends that, either in this case or any other where public powers intend to promote scientific and/or technological research, the guidelines of Law 25.467 are also followed so as to assure that decisions advance on solid ethical bases". Under the request of the SeCyT, the CECTE studied the issue concerning the technological and scientific research performed at public institutions financed by funds from the Office of Naval Research of the United States of America. The CECTE considered that "this case starts an important discussion to analyze the relationships among science, society and state." To that end, a four-relevant-item document was drafted, which may be consulted within the network. (CECTE, 2005a and 2005b).

At the end of 2005, the SeCyT organized a joint meeting with the Max Planck partnership (Germany) where an important cooperation program was announced between German and Argentine scientists at the N&N, Biosciences and Complex Criminality areas (la Nación, 2005b; SeCyT, 2005).

In August, 2006, "the Minister of Economy and Production, Felisa Miceli, put into operation […] the Advisory Council of the Argentine Nanotechnology Foundation, an entity presided by herself, and which will set up and promote the development of nanosciences and micro- and nanotechnologies in our country" (SeCyT, 2006); and opened the door for broader participation by various companies, unlike her predecessor's policy, which was linked to a single company.

The Ministry of Economy created the Argentine Nanotechnology Foundation, when Roberto Lavagna was the Minister of the Finance office. As stated by Lidia Rodríguez, current spokesperson of the Foundation and advisor to the Ministry, the initiative had been fostered by the Lucent Technology company to obtain the financing for an exclusive product of that firm (currently Alcatel-Lucent) (Premici, 2007).

The FAN Advisory Council would be integrated by: Alberto Lamagna (CNEA) as president, Dr. Ernesto Julio Calvo (SeCyT-UBA) as secretary, Dr. Joaquín Valdez (INTI), Ricardo Sagarzazu (INVAP), Dr. Roberto Carlos Salvarezza (CONICET), Bach. Alberto Ridner (CONAE) and Eng. Adolfo Cerioni (INTA) as members.

In a radio broadcasting program it was stated that "to accept and correct mistakes always represents a positive attitude. It is also applied to science management, and this occurred within the nanotechnology field," referring to the discussion which emerged as regards the allocation of resources to a single research group linked to a single company (Argentine Science on Show window, 2006).

In August, 2006, the Government announced the opening of the first bid for financing initiatives on nanotechnology within the FAN program framework leading directly to production innovation or improvement, as pointed out during the press conference following the meeting headed by the President of the Nation with the Argentine Nanotechnology Foundation and officers from the economic office, such as the Minister of Economy and Production Felisa Miceli, the secretary of Industry Miguel Peirano, and representatives of the secretaries related to technological and scientific research. During the press conference, held by Minister Miceli and FAN´s treasurer, Dr. Lino Barañao, FAN's scope was explained: "As you already know, last year, by means of a Decree, the Argentine Nanotechnology Foundation was created, where the Minister of Economy is in charge of managing the Foundation. Since I began my management term, we have developed the implementation of this advisory council, the working plan", said Miceli. The creation of an idea-project bid was announced, opened between 7 August, 2006 and 31 October, 2006, where "the evaluation of projects submitted will be in charge of the Foundation advisory council, integrated by the representatives of every public body having technological research competence and of the University of Buenos Aires as well. Let me also tell you that, from the Foundation, financing to carry out all feasible projects will range between 50 and 80 per cent, up to a maximum of 2 million dollars," said the Minister. Barañao said, among other things, that the intention through FAN, is "to provide a different financing instrument, specifically aiming to apply that knowledge [on nanotechnology] to the development of new products or services, and forming the basis for new companies or enabling existing ones to increase their productivity." He later explained that it is "a process with a net production approach and it is thus developed within the Ministry of Economy environment and not within the Education, Science and Technology environment. [...] this model, if successful, may be extrapolated to other knowledge areas according to the management we intend to provide, a more flexible and dynamic management, maybe even closer to a business management of funds, i.e., the typical management of public funds for research and it would enable, in the short term, to achieve sound results to validate this new way of financing the scientific-technological activity" (Presidency of the Argentine Nation, 2006).

In a document used to promote the submission of ideas-projects, which may be found on the webpages of the FAN and of the Ministry of Science and Technology of Brazil as well, the "FAN Messages" are read to the research groups: "Excellence within the nanoscience environment shall be translated into market-feasible products and processes" and to companies: "To think 'in small proportions' will increase revenues in big proportions" (FAN, s/f a).

On 4 August, 2006, the Minister of Economy and Production Felisa Miceli, the Minister of Education Daniel Filmus, the Secretary of Economic Policy Oscar Tangelson and the BID Representative Daniel Oliveira, offered a conference on the "BID support to finance Science and Technology Programs." Miceli said that "the policy of a Decree approving a 280-million dollar financing granted by BID to Argentina in order to finance science and technology programs was becoming real." Filmus, on the other hand, said that "they are 280-million dollars granted by BID and, together with the Argentine counterpart,[11] represents the most relevant investement ever made by Argentina within the last few decades as regards science and technology." He also added, "these investments are going to be used not only for the development of national research centers and institutes [...] but at the same time an important portion of it, through credits and grants, and even through private bank participation, is going to reach companies intending to carry out development and innovation related to production improvement. Oliveira stated that "it is a highly relevant project by a modern country able to insert itself within the international fashionable markets and achieve a long-term sound development, based upon knowledge" (MECON, 2006).

The FAN Management Council ratified the recommendation from the Advisory Council, authorizing to proceed to the «Project Formulation» stage for those Ideas-Projects submitted by the following companies / institutions: Darmex S.A., Renacity Investment S.A., CONAE-INTI, Bell Export S.A., Fundación Instituto Leloir, Fundación Proteger, OVER S.R.L., CNEA-CONAE, Nanotek S.A. (FAN, s/f b). The FAN adopted a new intake system of Ideas-Projects, where "under this mode, the companies and / or institutions interested may submit their support applications whenever they have any interesting Idea-Project, with no dates specified beforehand" (FAN s/f c).

It might be said that once the first Ideas-Project selection for possible fund granting has been achieved, FAN's cycle began, which is closely connected to credit provision by the State to foster development of the N&N field. That impulse, as it may be seen, has been mediated by various interests (economical, political, ideological, technological, scientific, academic, socio-cultural, etc.) and it has involved conflicts among the involved parties, directly or indirectly. It should be noted that once the operation and implementation arguments were overcome, there still remained various debates concerning the real impact on society, the clearance of lobbies in pursuit of solid benefits, the ecological-economical scope of said benefits, among other aspects. Those debates and reflections have not been highly visible under this initial effort to promote the development of a new technological area; nevertheless, at the *Nano-Mercosur Meeting 2007*, organized by FAN in order to promote the relationship between science and enterprise and among MER-

11 They amounted to 230-million dollars. It may be accessed via: http://www.scidev.net/gateways/index.cfm?fuseaction=readitem&rgwid=1&item=News&itemid=3055&language=2&CFID=2704407&CFTOKEN=43613411

COSUR´s partners, they were hesitant to include the first board on Nanotechnology and Environment (FAN, 2007).

Links between Argentina and Brazil on nanosciences and nanotechnologies

From November 1 to 4, 2004, at the Sociedad Rural de Buenos Aires, the meeting "Science, Technology and Society" was held, promoted by the Asociación Argentina para el Progreso de las Ciencias (AAPC) [Argentine Association for Science Progress] and the Sociedad Brasilera para el Progreso de las Ciencias (SBPC) [Brazilian Society for Science Progress]. At the roundtable "Evaluation for the creation of a Nanotechnology and Nanoscience network for Mercosur," the moderators of which were Roberto Salvarezza (INIFTA, Ar), Oswaldo Luiz Alves (UNICAMP, Br) and Celso Pinto de Melo (UFPE, Br), participants from both countries discussed:

The need to promote scientific exchange, foster and perform technological and scientific research projects, aiming to solve mutual interest problems, grant scholarships, offer specialization courses, etc., and have a budget available for that purpose. As a result of the debate, unanimously agreed and approved by audience, the Argentine and Brazilian authorities proposed to create a Nanoscience and Nanotechnology Binational Center" (Salvarezza et al, 2004).

That very day (02/11/2004), "the Ministers of science and technology of Argentina and Brazil signed a cooperation agreement aiming to ease the exchange of information and promote integration" (La Nación.com, 2004). Both officials considered that "the social and economical development in both countries depends upon growing, multiannual and non- bureaucratic public investments on basic and applied science," and that "it is necessary to increase the number of qualified human resources within all areas, which is essential to encourage a productive, innovative, efficient system, without which the equitable and sustainable development levels will be hard to attain by the relative national companies" (La Nación, 2004).

In a meeting held at the Secretary of Science, Technology and Productive Innovation on August 18, 2005 (Conicet, 2005; MCT, 2005), a task force integrated by J. Humberto Nicola, A. de Souza Mendes, J. d'Albuquerque e Castro, J. Dupont, on behalf of Brazil, and A. Menvielle, E. Calvo, A. Lamagna, A. Boselli and S. Bidart on behalf of Argentina, the work toward forming such a center was deepened. "The proposal was officially taken during the Third Meeting of the High Level Manager of both countries held on August 23 and 24 in Brasilia. The goals of the future Centro Brasilero-Argentino de Nanotecnología (CBAN)[12] [Argen-

12 In Argentina the center was known as: Centro Argentino Brasileño de Nanociencia y Nanotecnología, CABNN [Argentine-Brazilian Center of Nanotechnology and Nanoscience].

tine-Brazilian Center of Nanotechnology] were therein stipulated and an activity program was defined" (Conicet, 2005; MCT, 2005). Finally, on November 30, 2005, on the Argentine-Brazilian Friendship Day, at Foz de Iguaçu, the governments from Brazil and Argentina subscribed the protocol to create the CBAN.

According to this protocol, the center has the following goals: promote the exchange and transfer of technological and scientific knowledge, the creation and training of human resources in both countries; create and perform, through research cores, development and research projects addressed to provide knowledge, products and processes and support to social and/or economical interest laboratories for both countries; perform studies and operational mechanism proposals to integrate the private and public sectors, fostering the creation of bi-national employment for manufacturing nanotechnological processes and products; and, to study issues concerning patents, industrial rights and copyright for nanotechnological processes and products marketing.

The Center's structure consists of the Argentina-Brazil High Level Manager-Committee, the National Coordinators, a Bi-national Advisory Committee and an Executive Secretary in each country. The National Coordinators execute the Center's Management and periodically perform the Work Program on Nanotechnology and Nanosciences, which is sent to the High Level Manager-Committee. The Advisory Committee proposes projects and shares the evaluation of Work Programs adopted by the Center. The protocol additionally stipulates that both Governments will contribute, in equal parts, to finance the CBAN Work Programs.

In 2006, the Brazilian (Profs. Jairton Dupont and José d'Albuquerque e Castro) and Argentine (Profs. Ernesto Calvo and Alberto Lamaña) Coordinators were appointed by their relative Governments.

Between 2005 and 2006, the CBAN held the Seminar "Nanotechnology and Enterprises" in Buenos Aires (from 21 to 25 November, 2005), with the attendance of scientists and representatives from companies of both countries, and, the "Nanoparticle School", performed in Buenos Aires (from 25 May to 7 June, 2006). This school was attended by 60 students, 44 from Argentina, 13 from Brazil, two from Chile and one from Uruguay (CABNN, s/f).

The Centro Argentino-Brasileño de Nanociencia y Nanotecnología performed, on 6 and 7 August, 2007, a Work Meeting on the various areas covering the Nanotechnology and Nanoscience activity. It was attended by 40 experts from Argentina and Brazil, with its purpose to deepen the interaction between researchers and technologists and intensify the cooperation activities between both countries (CABNN, s/f).

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NOELA INVERNIZZI[1]

Brazilian Scientists Embrace Nanotechnologies

Introduction

Beginning in 2001, programs and funds for research into nanosciences and nanotechnologies (N&N) – the study and manipulation of matter at the atomic or molecular level – gained importance in science and technology (S&T) policies worldwide.[2] Brazil quickly became part of this trend. From late-2000 through 2004, several events occurred that would galvanize an active policy for the sector and culminated in the N&N Development Program (PDN&N) as part of the Multi-Year Plan for 2004-2007 of the Ministry of Science & Technology (MCT). After, the government launched the Industrial Technological and Trade Policy, which identifies nanotechnology as a strategic area. Both policies were synthesized in 2005 into the Nanotechnology National Program.

Introduced as a revolutionary area of study, N&N entered the arena of S&T policy and were presented to the media and the general public wrapped in a euphoria of visions of a future nanotechnological society. These visions were revolutionary not only in a technological sense but also in social and cultural terms. Their content was not just cognitive, but also involved interests, values, ideologies and concepts concerning the relationship between S&T and society (Grundwald et al, 2004: 56). Let us consider for instance a report prepared for President Clinton entitled *Nanotechnologies: Shaping the World Atom by Atom* (NSTC, 1999). This title became a slogan for nanotechnology, putting forward a notion of a material world under an unprecedented degree of human control and precision (McNaghten et al., 2005). Equally suggestive was the title of another report on converging technologies: *Converging Technologies for Improving Human Performance* (Roco & Bainbridge, 2005). N&N foretold the enhancement of human physical and cognitive capacity[3], the convergence of man and machine. This transhumanism is considered the most advanced stage of human culture.

These visions, with their promises, seek to form and legitimize an emerging field of research, guarantee funding and, naturally, influence the course of the technological development itself. However, these visions of techno-scientific progress also led to criticism and public debate. In the case of N&N, the debate be-

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2 In that year, President Clinton launched the National Nanotechnology Initiative, soon followed by N&N programs in other developed countries.

3 “Human enhancement” is the increase of cognitive human capacities for work, heightening senses and prolonging of life through nanotechnology devices combined with other technologies, integrated with the organism.

gan early on in developed countries and in the wake of the previous conflicts on biotechnology, many countries included in their N&N policies mechanisms for public information and participation. In this environment we have seen both visions designed to gain public acceptance and political support for research programs and those attempting to create resistance to specific technologies or programs.

Nevertheless, it is difficult to determine the precise impact of a vision or the dynamic of contradictions between diverging visions on the concrete configuration of research programs and the resulting technological developments. Vision assessment, a tool integrated with technology assessment allows us to approach this matter. According to Fiedeler et al., (2005), the purpose of S&T vision assessment is to analyze the sense, role, bases, values and interests subjacent to the visions in order to understand their influence on the dynamic of the debate in a specific technological field.

In this article, we propose to map and analyze the visions of N&N disseminated by Brazilian scientists working in that field to the rest of the scientific community through the *Jornal da Ciência* (JC, Journal of Science). The J*ornal da Ciência*, an informative journal published by the Brazilian Society for the Progress of Science since 1985, forwards to its 14,500 subscribers news, articles and opinion papers on S&T issues. These subscribers are mainly researchers, university professors and graduate students. It is worth noting that the Brazilian Society for the Progress of Science is an independent association of scientists with considerable influence on science and technology policy. The journal includes articles submitted by scientists, information gathered from or sent by S&T agencies and relevant reports from the national press. Most of these reports are either penned by the scientists themselves or their opinions are used by journalists as a quoted source. Reports on N&N were analyzed from the years 2002, 2003 and 2004, which was a key period in the structuring of N&N policy in Brazil.

Over these three years, N&N appeared frequently in the JC. In 2002, 24 reports were published, rising to 40 in 2003 and 61 in 2004. The subjects broached can be seen in Table 1. In 2002, reports about this new field and its applications based on domestic and international research information were predominant. In 2003, the focus was on the debate over N&N policy that was in the works, with general reports about the field of study continuing. In 2004 the reports included general information, discussions over policy, infrastructure and the organization of research. It was at this time that the matter of social and ethical implications arose, along with the risks of nanotechnologies. We also saw an increase in information about events, announcements, fairs and conferences on N&N at this time, signaling the gradual introduction of the field into everyday research in the country.

4 The Journal of Science is not a scientific journal, but an informative journal for academics and researchers. Therefore, the articles submitted are not peer-reviewed. The Editor and a team of journalists are responsible for selecting the articles published. The JC is also distributed in printed form every two weeks. See http://www.jornaldaciencia.org.br/index2.jsp

Table 1
Main subjects broached in reports

	2002	2003	2004
General information on nano and its applications	7	5	6
International research reports	4	4	2
Brazilian research reports	2	1	3
S&T policies and financing for the sector in Brazil	3	12	7
Infrastructure, HR and organization of research in Brazil	3	0	6
Risks and economic, social, legal and ethical implications.	0	2	6
Sub total of reports	**21**	**24**	**30**
Information about events, courses, fairs, announcements, etc.	5	16	31
Total reports	**24**	**40**	**61**

Source: Prepared by the author based on information from the *Jornal da Ciência*

In section one we present a brief panorama of the most important events related to the development of the N&N policy in Brazil, with the purpose of putting the analysis of the different visions of N&N in context. In the following sections we explore the content of the articles. Those dealing with events, courses, fairs and announcements have been excluded from the qualitative analysis as they contain only specific information about these issues. We have organized the presentation of N&N visions into four sub-themes. First, we analyze visions on a future nanotechnological society, identifying the promises of nanosciences and nanotechnologies that are being made. Second, we examine whether these visions allude to social, economic and ethical implications and the potential risks of these new technologies. Third, we identify the main actors involved in spreading these visions. Finally, we analyze how they are used to legitimize a new field of research. We round off the article with a few brief considerations and reflections.

1. Development of the N&N Policy in Brazil

The creation of the national policy to develop N&N in Brazil began with a workshop held in Brasilia, in November 2000, called "Tendencies of Nanosciences and Nanotechnologies". This workshop was organized by the Secretariat of Policies and Programs of the Ministry of Science and Technology and the National Council for Scientific and Technological Development (CNPq). In this reunion, 32 researchers from different fields such as physics, chemistry, biology, and engineering reached an agreement about the necessity of creating a national program of N&N. An Articulation Group composed by ten researchers was created, with the purpose of identify the expertise of Brazil in N&N and elaborate an agenda (CNPq Noticias, 2000).

In April 2001, the Articulation Group presented a document identifying 192 researchers working in six areas connected to N&N in the country: a) Nanoinstruments, nanosensors and nanoelectronics, b) Nanoestructured materials, c) Nanobiotechnology and nanochemistry, d) Nanoscale processes with impacts and applications on the environment and agriculture and e) Nanometrology (Knobel, 2002).

In the same year, the CNPq acted rapidly in response to these reunions and it called for inter- and multidisciplinary research projects to run the Redes Cooperativas de Pesquisa Básica e Aplicada em Nanociências e Nanotecnologias (Cooperative Networks of Basic Applied Research on Nanosciences and Nanotechnologies) with the purpose of creating and consolidating the national expertise in this field (CNPq, 2001). Three Million reales were allocated for the project (one-million dollars according to the exchange rate at the time). The outcome was the creation of four research networks: Nanostructured materials, Molecular nanotechnology and interphases, Nanobiotechnology and the Network of semiconductor nanoinstruments and nanostructured materials. Each network was composed of scientists, universities and research centers from different parts of the country.[5]

In addition, the Ministry of Science and Technology (MCT) and the National Council for Scientific and Technological Development (CNPq) have promoted, since 2001, four institutes for research in new materials and nanosciences as part of the Millennium Initiative financed by the World Bank, whose goal is to push excellence-level scientific research in strategic areas for the development of the country (CNPq, 2007).

In the same year, the efforts of the Coordinação de Aperfeiçoamento do Pessoal de Nível Superior (CAPES) (Coordination for the Improvement of the High Level Personnel) of the Ministry of Education were integrated, granting six scholarships in Nanotechnology in partnerships with the Associação Brasileira de Luz Sincrotron (Brazilian Association of Synchrotron Light) (CAPES n/d).

The N&N policy that was conceived at the beginning of the government of Fernando Enrique Cardoso (1999-2002) had the purpose of creating a Nanotechnology Reference Center linked to the MCT. This center had the dual mission of stimulating academic research and encouraging the use of new technologies by the private sector. These ideas were embedded in the first Programa Nacional de Nanotecnologia (National Program of Nanotechnology) coordinated by the Physicists Cylon Gonçalves da Silva, Emeritus-Professor of the Universidade Estadual de Campinas and former director of the National Synchrotron Light Laboratory (Silva, 2003). Shortly after the change of government, the project was abandoned and the opening of the laboratory was cancelled because it was argued that the project consumed too many resources that could be used by other laboratories.

When Luis Ignacio Lula da Silva became president, the MCT created a new program, under the supervision of Dr. Fernando Galembeck, another professor of the Universidade Estadual de Campinas. In 2003, a Working Group, coordinated by Gallembeck, was created by the MCT to develop a National Program of Nanoscience and Nanotechnology. The final proposal was submitted to public con-

5 These four networks worked until October 2005, but from a new call of the CNPq 10 new networks were created, all of them connected to the Brazil Nano Program.

sultation and it was later incorporated to the Plan Pluri Anual 2004-2007 (Multi-year Plan 2004-2007) of the MCT. The estimated budget for the four year project was 78-million reales (approximately USD 28-million).

The objective of the program was to develop new products and processes from nanotechnology with the idea of increasing the competitiveness of national industry. For that reason, it recommended actions to implement and support laboratories and networks, working with nanotechnology and the implementation of institutional projects focusing on R&D of the N&N (MCT, n/d)

Also in 2004 and parallel to this, the government took control of the Industrial Technological and Trade Policy, including nanotechnology policy which it depicted as "bearer of the future." This reinforced the strategic importance that the government granted to this field (Teixeira, 2005). The year 2004 was also decisive for the organization of collaborations with the Argentinean Republic, through the creation of the Bi-national Center for Nanotechnology Brasil-Argentina.

At the end of the year, the Programa Brazil Nano (Brazil Nano Program) was created to bring together the National Program of Nanoscience and Nanotechnology and other actions on nanotechnologies included in the Industrial, Technological and Trade Policy. In this context, a year later, the CNPq launched a new call to create research networks and ten networks were opened which are still operating. The research profile of these networks reflects an orientation towards industrial application.

Still in 2004, the MCT again proposed the construction of a National Laboratory of Micro- and Nanotechnology worth 30-million reales, in São Paulo, generating a significant debate.[6] It generated a powerful reaction from the expert scientists of the area, who observed this as a centralizing measure in distributing the scarce resources and as an action contrary to the recommendations from the PPA 2004-2007. It also was viewed as a serious questioning of the cooperative networks policy, that was previously evaluated as successful (Jornal da Ciência, 2004a). The debate is still open.

President Lula da Silva and the Minister of Science and Technology, Sergio Rezende, launched the Programa Nacional de Nanotecnología (National Nanotechnology Program) in August 2005, with a budget of 71-million reales (USD $31-million dollars) for the 2005-2006 period. This program consolidated several of the previous initiatives, particularly the one from the PPA 2004-2007 and the orientation of the Industrial, Technological and Trade Policy. The additional funds doubled the estimate by the PPA 2004-2007 (*Jornal da Ciencia*, 2004 b; MCT, n/d).

Several nanotechnology laboratories were financially supported through 2006, including the creation of the National Nanotechnology Laboratory for Agro-Business, expanding the research infrastructure of the country.

6 This project is, again, a proposal from Cylon Goncalves da Silva, who is returning with a high position to the MCT.

In 2007, the Ministry of Science and Technology published the 2007-2010 Action Plan, in which nanotechnology is highlighted and for the first time, established within public policy the need to analyze ethical questions and the social impact resulting from the use of nanotechnology products (MCT, 2007).

2. The promises of nanosciences and nanotechnologies

The articles and reports introduce N&N as being revolutionary, using expressions such as "technological revolution", "change of paradigm", "rupture" and "industrial revolution". The main benefit of this revolution would be economic development (Table 2). In 2004, the benefits of nanomedicine for improving health and quality of life were also highlighted, as well as the potentials of nanotechnology for preserving the environment and reversing environmental degradation.

Table 2
Potential benefits resulting from N&N research

	2002	2003	2004
Economic development	9	13	10
Health and quality of life	1	3	11
Preservation of the environment	2	2	5
Benefits for humanity	0	0	2
The article does not broach the subject	11 / 20	9 / 24	13 / 30

Note: More than one option is possible
Source: Prepared by the author based on information from the *Jornal da Ciência*

In the JC, the visions of the nanotechnological society tend to be more conservative than those that generally characterize the international debate. No one speaks of cyborgs. There is no mention of the controversial subject of molecular manufacturing, as discussed by Eric Drexler (1986).[7] Emphasis is placed on less futuristic subjects such as the efficiency of new products: better focused therapies, permanent monitoring of the body, extremely powerful computers, intelligent multi-functional clothing and more resistant and longer- lasting materials. Table 3 shows the main areas for the application of these N&N referred to in the articles: health and computers, followed by new products and materials. In Table 4 we provide some examples of the visions of efficiency in these areas.

7 The more radical visions of nanotechnology, such as that of Eric Drexler (1986), foresee possible production by way of molecular machines capable of replicating themselves and breaking away from human control, leading to a "gray goo" which would contaminate the planet.

Table 3
Most frequently mentioned fields for the application of nanotechnologies

	2002	2003	2004
Pharmaceuticals, prosthetics, health	10	7	10
Computers, microelectronics, nanoelectronics	10	6	7
New materials	4	4	5
Cosmetics	1	2	4
Devices for products and productive processes	5	3	2
Production and storage of energy	0	1	3
Telecommunications	0	2	3
Chemical and petrochemical industry	3	1	1
Agriculture and agro-industry	3	7	0
Nanomachinery	3	0	0
Known consumer products with new features	3	6	2
Article does not specify a field of application	1 / 20	10 / 24	15 / 30

Note: More than one option is possible
Source: Prepared by the author based on information from the *Jornal da Ciência*

These visions are set in the immediate future, the next ten- to fifteen-years, a period that anticipates a huge surge in the nanoproducts market. This temporal horizon ties in with the emphasis on commercial viability and ready availability for the use of the products that are being researched today, as seen in over half of the articles analyzed. Moreover, the visions analyzed also differ from those in the in-

Table 4
What does nanotechnology have in store for us? Examples

2002	2003	2004
	Health	
Nanocomputers will navigate in the body to monitor drug delivery	Treatment with nanoparticles selectively absorbed by cancerous tissue	Brain cells will be reconstructed, leading to the cure of a number of diseases
Nanomachinery which will be able to operate even inside a living cell	From solar filters to cancer treatments…	Nanolaboratories capable of navigating in the human body to monitor the emergence of diseases and provide treatment for diseases through nanotherapies
Substitution of body parts reproduced from molecules		Use of nano robots to apply medication to specific cells
	Computers, microelectronics	
Building of nanocircuits using biological materials (biochemical properties of DNA)	Faster, more compact computers with greater memory capacity	Much smaller computers with greater memory capacity
Molecular computers that are 1000 times more powerful than those of today		Extremely quick and powerful computers
	New materials and products with new features	
Anti-collision sensors for cars	Carbon nanotubes in textiles capable of storing energy, picking up radio signals or working as sensors	Spectacles that will not get scratched Self-cleaning glass
New, lighter materials for planes	Odor remover for bathrooms using gold nanoparticles	Tires that last sixteen times longer than today's
Glass and lenses that reduce the intensity of sunrays	Self-cleaning glass	Intelligent, stainless clothing that does not wrinkle. Uniforms for soldiers to protect them from biological attacks

Source: Prepared by the author based on information from the *Jornal da Ciência* ternational debate, in which the implications of nanosciences and nanotechnologies in the long term are also considered (Wood et al., 2003).

3. Economic, social and ethical implications and potential risks

The echoes of the polarized international debate on the implications, risks and regulation of N&N are practically unheard among the Brazilian scientific community.[8] Subjects such as information and public participation, evaluation of risks, ELSI studies (ethical, legal and social issues of technology) are not only part of the international debate but also issues addressed by policies for the development of N&N, with a specific budget in most of the more advanced countries. From the selection of some topics that stand out in the international debate, listed in Table 5, we sought to map out the importance given to these matters in the JC reports.[9] Among the economic implications, most attention is paid to the change in production conditions and competitiveness. However, we can see that most of the articles do not touch on these questions.

In 2003 the ETC Group called for a moratorium on nanotechnology, pointing out possible risks to health and the environment at the World Summit on Sustainable Development held in Johannesburg. This call was highly controversial. However, in the JC, it was only raised in one report. In 2004, two events introduced the theme of risks: the foundation of the Nanotechnology, Society and Environment Network in Brazil and the publication of the report of the Royal Society and the Royal Academy of Engineering (RS&RAE, 2004).

Indeed, the scientific community "doesn't talk" to outsiders such as NGOs or social movements that have spoken of the possible risks and social and ethical implications of N&N. References to potential conflicts between science and the public over N&N is scarce, although the sensitivity of the scientists to the possibi-

Table 5
Main social, economic and ethical implications of nanotechnology

	2002	2003	2004
Changes in conditions for production and competitiveness	3	5	3
Obsolescence of technologies, products and materials	3	1	2
Fall in traditional exports	0	1	0
Changes in way of life	0	1	3
Greater social inequality	0	1	2
Ethical dilemmas	0	1	1
Risks to health and the environment	0	2	7
Risks to workers in laboratories and industry	0	0	1
The article does not broach the subject	13 / 20	16 / 24	20 / 30

Note: More than one option is possible.
Source: Prepared by the author based on information from the *Jornal da Ciência*

8 See for example UNESCO (2006), Invernizzi & Foladori (2005); Wood et al (2003);
9 The selection of topics was done based on previous research (Cf. Invernizzi & Foladori, 2005 and Foladori & Invernizzi, 2005).

lity of new conflicts would have been heightened by what had been happening in the country because of the controversy surrounding genetically modified organisms (Pelaez & Schmidt, 2000). Among the few references to society, we found some that attempt to dismiss the capacity or legitimacy of NGOs to voice their opinions on nanotechnology. One researcher, for instance, recognizes the existence of the risks of nanoparticles to human health and the environment. He says these risks are low and avoidable and speaks of the need to inform the public in order to "face activists who fight, armed only with popular fantasies, [and who] are organized against this type of science, demanding a moratorium" (Garcia, E, 2004). Another scientists informs us during an interview that there are already cosmetics with nanoparticles on the market but that the companies who make them do not make this public "so that they won't suffer with NGOs" (Geraque, E, 2004). It is necessary to note that both emphasize the importance of scientific information for the public, but they do not recognize the right of social movements to voice their opinions on technologies, their implications and their potential risks. A good question in this context is: would environmental regulation be on international agendas today if social movements had not started protesting against pollution and environmental degradation forty years ago?

4. Legitimizing the Field

Brazilian scientists introduce N&N as a revolutionary field that is about to take off, with a huge potential for benefits, and a fabulous market being developed over the next few years.[10] They endorse linear visions of progress. Possible social implications and risks are so marginally considered that they do not cast a shadow on this optimist vision of the nanotechnological future. To legitimize the field of research, scientists stress these visions of progress by means of three arguments: opportunity, necessity and viability.

The scientists have repeatedly characterized N&N as a change in the scientific and technological paradigm that will open up a historic *opportunity* for Brazil. The PDN&N clearly supports this point of view when it states in its justifications that: "in an imminent breaking of paradigms due to nanotechnology and nanosciences (N&N) we are now faced with a unique opportunity to join this new era along with developed countries…" (STM 2003:8). From opportunity comes the necessity of developing aggressive policies and investing resources because, if this is not done, Brazil will remain outside of this new paradigm in which so many countries are investing so quickly. Metaphors such as "we can't miss the bus" or "we've got to catch this wave" are used a great deal.

10 Lux Research (2006) estimates that the nanoproduct market will be worth US$2,900,000,000,000 (2.9 x 1012) in 2015.

In 2003, during the preparation of the Development Plan for Nanosciences and Nanotechnologies (PDN&N), the argument of national *capacity* was often used. It was argued that the networks cooperating in N&N research, created following an announcement by the CNPq (Brazilian Research Council) in 2001, gathered highly qualified and productive human resources capable of advancing world-class research and pushing innovation towards the promising nanoproduct market. The greatest obstacle, according to the scientists, is the lack of resources for improving infrastructure and increasing the size of the research team.

It is worth mentioning that in the midst of all the discussions surrounding the approval of the Law of Innovation, the relationship between capacity for research and capacity for innovation by the productive sector was discussed very little by scientists. This is significant because the goals of the PDN&N and the discourse of the scientists strongly agree in the basis of a need to support N&N research in Brazil: the development of national competitiveness (see Table 6). Other arguments such as technological autonomy, sustainable development and meeting social needs at a national level are only marginally utilized to legitimize the field of research.

5. Main Actors

Within the scientific community that carries out N&N research, there are actors who have an outstanding role in the promotion of certain visions concerning nanotechnology. The scientists most mentioned in the JC are physicists. In Table 7, we can see that they have a profile considered to be of excellence in national research and they are the product of the investment that has been made in the country since the 1970s in order to achieve this development: they have obtained their doctorate degrees at the most renowned universities in Brazil and overseas and have carried out their post-doctoral research at universities and research centers abroad. Most of them work at universities and research centers in São Paulo State, where the S&T infrastructure is concentrated. It is worth noting, however, that in N&N, the Northeastern region also stands out, due to the excellence group at the

Table 6

Main reasons to justify support for nanotechnology research in Brazil

	2002	2003	2004
To develop competitiveness to enter the international market	6	7	6
N&N is a strategic field. Brazil cannot fall behind	3	2	3
To train qualified human resources	0	2	2
To meet local social needs	0	1	0
To gain technological autonomy	0	0	1
Sustainable development	0	0	1
The article does not broach the subject	12 / 20	12 / 24	21 / 31

Note: More than one option is possible.
Source: Prepared by the author based on information from the *Jornal da Ciência*

Federal University of the State of Pernambuco. In other words, the most active scientists in spreading visions on N&N are the elite of the national scientific community.

Table 7
Academic profile of researchers quoted in articles

	2002	2003	2004	Total
Predominantly qualified in physics	9	12	9	30
Predominantly qualified in chemistry	0	4	5	9
Predominantly qualified in engineering	1	3	4	8
Predominantly qualified in pharmaceuticals, biochemistry and medicine	3	1	2	6
Predominantly qualified in social, human and applied sciences	1	1	2	4
Post doctorate and other qualifications overseas	10	16	12	38
Doctorate degree overseas	7	10	10	27
Master's degree overseas	1	1	0	2
Doctorate degree in Brazil	6	11	11	28
Master's degree in Brazil	11	12	14	37
Work at universities or research centers in São Paulo State	8	11	13	32
Work at universities or research centers in Rio de Janeiro, Minas Gerais and the Southern Region of Brazil	0	4	4	8
Work at universities or research centers in the Northeast of Brazil	3	5	5	13
Work at universities or research centers in other Brazilian states	1	1	0	2
Researchers with connections to companies	1	0	0	1
Total number of researchers quoted	12	20	25	57
No information available about the researchers	0	2	3	5

Source: Prepared by the author based on information from the *Jornal da Ciência* and the Curriculos Lattes data base of the CNPq.

Only four social scientists are cited in the articles analyzed, demonstrating both the scarce attention paid to the economic, social and ethical implications of N&N, and the still-limited familiarization of Brazilian social scientists with the coming nanotechnology revolution.

Comments and reflections

The definition of a national policy for N&N was legitimized by the elite of the scientific community before the rest of the community and the public through visions of progress, efficiency and competitiveness. Brazil is facing a technological revolution that it cannot afford to ignore.

These visions are linked to a linear perspective of progress, according to which investment in S&T, transformed into innovation, will result in greater competitiveness. More efficient technologies and a more competitive country will, in turn, lead to social well-being. This mechanicist perspective is questionable for a very unequal country like Brazil. In fact, the poverty gap has widened globally while technology has developed fast over the past few decades (PNUD, 2005; Invernizzi & Foladori, 2005). On the other hand, a technological revolution at the level being announced will have highly destabilizing implications and its effects will hit the most vulnerable sectors of society hardest.

The international debate on N&N has emphasized the need to democratize decision-making to influence the development of this technology in order to democratize its benefits, limit its risks, and face its social, economic and ethical implications. However, the scientists who are developing nanosciences and nanotechnologies in Brazil are reluctant about having new actors in the S&T debates. This could lead to conflicts between science and society and the loss of public confidence in S&T.

The reconfiguration of the relationship between science and society is still quite new and restricted to more advanced countries (Invernizzi, 2005). Most scientists in Brazil were certainly not trained in this paradigm of a closer relationship between science and society. To make advances in this way requires greater interaction among scientists from the natural and physical fields and social scientists to reflect on the research policies of the country. It also means incorporating new social actors into the dialogue, actors who doubtless endorse specific interests, as is common in the democratic game.

The N&N policies of developed countries include a number of mechanisms for public participation. Brazil needs to join this trend to be in a position to guide the development of nanotechnologies democratically so that they are in line with the social needs of the country, with the Precautionary Principle as a guide for potential risks and the evaluation of economic, social and ethical implications as a reference for concomitantly preparing policies that face the potential problems that may arise in these fields.

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GUILLERMO FOLADORI, EDGAR ZAYAGO LAU

Tracking Nanotechnology in México[1]

Introduction

In Latin America, Brazil, Argentina and México are countries where nanotechnology research is being further developed (Foladori, 2006a).[2] However, there are differences between them. In 2001, Brazil introduced a national plan to form scientific research networks with a one million dollar budget. Later, in 2004, it announced the Nanoscience and Nanotechnology Program, within the framework of the *Plano Plurianual de Desenvolvimento 2004-2007* (The Pluri Annual Plan for Development 2004-2007), for which the Brazilian Government allocated thirty-nine (39) million dollars (MCT, 2004a, 2004b). Additionally, there are several funds from federal, provincial and international sources to sponsor nanotechnology research in Brazil. Most of these resources are centrally managed by the Ministry of Science and Technology in Brazil with the objective of advancing nanotechnology research.

The Government of Argentina, on the other hand, in 2005 created the *Fundación Argentina de Nanotecnología* (the Argentinean Foundation of Nanotechnology), with an estimated budget of ten (10) million dollars to cover research in nanotechnology for five years. This project was criticized due to the vague rules and procedures that its implementation entailed. One and a half years later, civil society groups were still censuring the project (Foladori, 2005, 2006b). Even so, the Argentinean and Brazilian governments are trying to regulate all nanotechnology related research by controlling budgets and by implementing supervisory procedures. Neither Argentina nor Brazil have set up discussion panels to examine the political, social and economic implications of the use of nanotechnology. In both countries, the exchange of ideas about the use of nanotechnology can only be associated with the idea of becoming more competitive (Foladori, 2006a). In 2005, Argentina and Brazil signed an agreement which lead to the creation of the *Centro Brasil-Argentina de Nanociencias y Nanotecnología* (The Brazil-Argentina Center of Nanotechnology and Nanosciences). This center offers training courses and encourages scientific exchange between diverse research networks (Almeida, 2005).

It is worth mentioning that neither Brazil, nor Argentina, nor México have created programs to examine the possible social, economic, environmental, political

1 Reproduced from *Nanotechnology Law & Business Journal*, 4(2), 211-222.

2 Foladori, (2006). Cuba has made important advances in nanobiotechnology and there are research teams at various institutions in other countries, which should not be overlooked; but Cuban advances are not discussed herein. This article uses the term “nanotechnology” to also refer to all nanosciences.

and ethical impacts of the use of nanotechnology.[3] In contrast, most of the industrialized countries have solid agendas to promote the discussion of these issues. The absence of such schemes in Latin America indicates a lack of public awareness about the use of this technology and shows the profound hope that the governments in the region have in nanotechnology to conquer international markets, even though its use would entail risks and impacts not fully understood.

The Mexican case is somewhat different from the Argentinean and Brazilian cases. There is no specific plan or national program linked to nanotechnology in México, even though nanotechnology is considered a strategic sector for development, as identified in 2002 in the Programa Especial de Ciencia y Tecnología 2001-2006 (Special Program on Science and Technology 2001-2006). There have been efforts from a group of scientists to promote such a plan (IPICyT, 2002). The United States-México Foundation for Science ("FUMEC") has shown support as well. In addition, nanotechnology research and development in México has been conducted by individuals and regulated through the bilateral and multilateral agreements that some research centers have signed. However, this reflects a path where specific interests regulate the development of nanotechnology.

Nanotechnology in Mexico

For the most part, there are two features that distinguish the nanotechnology initiatives in Argentina and Brazil from the Mexican. On one hand, México is missing a tangible plan for the development and research of nanotechnology. On the other, the United States plays an important role in most of the cooperation agreements signed by México and in the creation of new positions inside Mexican high technology industries. This last feature is, to some extent, logical since México and the United States are neighbor countries and both are members of the North American Free Trade Agreement ("NAFTA"). However, this relationship gives a special character to the development of nanotechnology in México.

1. Mexican Science and Technology Policy in Relation to Nanotechnology

At the beginning of 2002, all nanotechnology-related research became an area of strategic importance, with some funding directed to support its development. *The Programa Especial de Ciencia y Tecnología 2001-2006* (Special Program for

3 Brazil has a Network of Nanotechnology, Society and Environment which gather social scientists interested in those themes. See http://nanotecnologia.incubadora.fapesp.br/portal. In 2006, the Latin American Network of Nanotechnology and Society was formed, with similar interests across the region and headquartered in two Mexican institutions: The Doctorate in Development Studies at the Autonomous University of Zacatecas, and the Sciences and Humanities Interdisciplinary Research Center at the National Autonomous University of México ("UNAM"). See www.estudiosdeldesarrollo.net/relans.

Science and Technology 2001-2006), which is embedded inside the National Development Plan 2001-2006, views nanotechnology as a strategic area within the science of advanced materials. In the same document, the core areas to be developed are depicted in detail and include nanostructures, semiconductors, metallurgy, biomaterials, optical components, advance ceramics and modulation of materials and processes. Additionally, the Development Plan reviews the available resources in research centers with a special focus on human resources, equipment and the connections they have with industry. *The Programa Especial* points out the pressing need for creating a national plan on nanotechnology development and the necessity to encourage the formation of networks for scientific exchange in the area (CONACYT, 2002). Moreover, the National Development Plan 2001-2006 identifies nanotechnology research as an important subfield inside the energy sector, above all others within the framework of the *Instituto Mexicano del Petróleo* ("IMP") (Mexican Institute of Petroleum). The conditions and provisions to create and implement a National Initiative for Nanotechnology Development were present, but the lack of funding and the absence of an executive plan created barriers to fully develop a national initiative for nanotechnology. In this regard, the budget for Science and Technology ("S&T") has dramatically decreased in the last five years. In the National Development Plan, it was expected that the disbursement for Research and Development ("R&D") would reach 1% of Gross National Product ("GDP") by 2006. By 2004 this estimate was reduced to 0.5% of GDP and by 2005 it barely reached 0.4%. This could change at any time. One indicator of change is the report issued by the Committee for Science and Technology of the Senate of the Republic in 2005. In this document, the Committee pronounced itself in favor of preparation for a National Emergency Program for investment in research and teaching of nanotechnology (Comisión de Ciencia y Tecnología, Senado de la República, 2005).

Several researchers and specialists in the nanoscience field worked in a partnership to create the *Programa Especial de Ciencia y Tecnología 2001-2006*, reviewing a large number of national programs for nanotechnology research in other countries, particularly the National Nanotechnology Initiative of the U.S. After a review of nanotechnology initiatives, it is surprising that the Programa Especial does not make any reference to the possible risks to health and the environment related to the use of nanotechnology—neither its ethical and legal implications, nor the public participation in what many scientists see as the most important technological revolution of the 21st century. The absence of concern associated with the use of nanotechnology in México becomes worrying because of the increasing number of laboratories in the area. Furthermore, many of them are already using clean rooms and very sophisticated equipment with the main objective of encouraging the production of nanocomponents for the industrial sector. In the same vein, Argentina and Brazil do not have a program to discuss the implications and risks of nanotechnology, or a plan to supervise the activities related to nanotechnology research and development. In this regard, it is clear that the distance between Latin America and its European and North American counterparts is expanding.

Due to the absence of a National Nanotechnology Initiative, México has turned its attention to different research centers in search for bilateral or multilateral agreements to foster the creation of scientific networks in the area. A report, written by Malsch Technovaluation relating to micro- and nanotechnology in México, points out that there are eleven research groups located in three universities and two research institutes, with ninety researchers in the area of nanotechnology (Lieffering, 2004; Malsch, & Lieffering, 2004).

Other sources estimate the number of researchers working on nanotechnology in México at between 300 and 500. It is beyond the aim of this article to provide a complete picture of the status of nanotechnology in México, but it is worth mentioning some of the efforts made in this regard.

The *Universidad Nacional Autónoma de México* ("UNAM") (National Autonomous University of México) is by far the university with the highest concentration of researchers working on nanotechnology and some of the most ambitious projects. For instance, the Impulsa program was created to promote multidisciplinary research in a variety of areas with the aim of solving problems at the national level. One such approach is the University Project for Nanotechnology, approved in December 2004, in which the main objective is to develop nanostructured materials as catalysts for environmental improvement. This project manages one million dollars per year and has thirty (30) researchers from eight (8) different departments at UNAM (PUNTA, 2004; Calles, 2005). In addition, UNAM has an internal research network for nanotechnology called *Red de Grupos de Investigación en Nanociencias REGINA* (Research Network Groups on Nanosciences), which groups together 40 or more researchers in 8 research centers of UNAM. Most of these centers are located in México City, but there are others in the provinces such as the Center for Condensed Matter Sciences in North Baja California, or the Center of Research in Energy ("CIE") in Morelos.

The *Centro de Investigación y Estudios Avanzados* ("CINESTAV") (Advanzed Studies and Research Center) of the *Instituto Politécnico Nacional* ("IPN") (National Polytechnical Institute) is one of the most important research centers in México. It has several campuses doing nanotechnology-related research. The physics department, located in México City, has a laboratory focusing on semiconductor nanostructures. On the Guanajuato campus you can find the National Laboratory in Genomic Science. Nanotechnology is also the subject of study in the physics department at the Merida Campus; metallurgical engineering at Coahuila; electrical engineering at Guadalajara and special materials at Querétaro. The academic production from CINESTAV is present in several scientific magazines and in dozens of international symposiums.

The *Instituto Potosino de Investigación Científica y Tecnológica* ("IPICyT")

(Potosí Institute of Scientific and Technological Research), a center within the *Consejo Nacional de Ciencia y Tecnología* ("CONACYT") (National Council of Science and Technology), promotes research and training in nanotechnology. In cooperation with FUMEC, it has been fostering the development of a National Plan on Nanotechnology Research. The Advanced Materials Research Group studies the properties of nanostructures and materials. The research conducted there has been internationally recognized for its quality. The IPICyT is also a member of the European consortium NANOFORUMEULA.

The *Benemérita Universidad Autónoma de Puebla* ("BUAP") (Honorable Autonomous University of Puebla) stands out, particularly in the area of semiconductors, and is the center of operations for the International Network of Nanoscience and Nanotechnology. There are several researchers involved in the network, coming from different institutions such as BUAP, the *Instituto Nacional de Neurología y Neurocirugía* ("INNyN") (National Institute of Neurology and Neurosurgery), which is part of the National Institutes of Health in México, the *Sección de Estudios de Posgrado e Investigación de la Escuela Superior de Ingeniería Mecánica y Eléctrica* ("SePI-ESIME") (Department of Postgraduate Studies and Research of the Advanced School of Mechanical and Electric Engineering) of the IPN, the *Universidad Autónoma Metropolitana-Iztapalapa* ("UAM-I") (Autonomous Metropolitan University-Iztapalapa), the Zacatenco and Merida units of CINESTAV, UNAM and the *Instituto Nacional de Investigaciones Nucleares* ("ININ") (National Institute of Nuclear Research).

One of the most important public enterprises doing nanotechnology-related research is the IMP, which currently has several research projects. Scientists from IMP have patented some successful results and they have a special program with the objective of creating human resources in the area of molecular engineering. In addition, this institute has signed several agreements within México, such as the Electrochemical Accord with UAM-I. This agreement included the establishment of an advanced laboratory and the financing of an R&D project in the university (Ramos, 2004). UAM-I, through its laboratory of Nanotechnology and Molecular Engineering, has several agreements with other institutions (QuimiNet.com, 2005).

In México, there are other universities and research centers working with nanotechnology, several of which participate in international agreements and form clusters of industrial development. For instance, the *Centro de Investigaciones en Materiales Avanzados* ("CIMAV") (Center of Advanced Research Materials) of CONACYT; la *Universidad Autónoma de Nuevo León* ("UANL") (the Autonomous University of Nuevo León) has a nanotechnology laboratory doing research on health issues and The *Universidad Veracruzana* ("UV") (Veracruzana University) has a research center on micro- and nanotechnology specializing in magnetic sensors. Other centers include the *Universidad Autónoma del Estado de México* ("UAEM") (Autonomous University of the State of México), the

Universidad de Guadalajara ("U de G") (University of Guadalajara), la *Universidad Autónoma de San Luis Potosí* ("UASLP") (Autonomous University of San Luis Potosí), the *Instituto Tecnológico de Estudios Superiores de Monterrey* ("ITESM") (Technological Institute of Higher Studies of Monterrey), the *Instituto Tecnológico Superior de Irapuato* ("ITESI") (Technologic Institute of Higher Studies of Irapuato), the *Instituto Nacional de Astrofísica, Óptica y Electrónica* ("INAOE") (National Institute of Astrophysics, Optics and Electronics), the *Universidad de Guanajuato* ("UGTO") (University of Guanajuato), the *Universidad Tecnológica de México* ("UNITEC") (Technological University of México), the *Universidad Autónoma de Ciudad Juárez* ("UACJ") (Autonomous University of Ciudad Juárez), the *Centro de Investigación Científica y de Educación Superior de Ensenada* ("CICESE") (Center for Scientific Research and Higher Studies of Ensenada) of CONACYT, the *Centro de Investigación en Química Aplicada* ("CIQA") (Research Center of Applied Chemistry) of CONACYT, the *Centro de Investigaciones en Óptica* ("CIO") (Research Center for Optic Science) and the *Universidad Politécnica de Pachuca* ("UPP") (Polytechnical University of Pachuca).

There are important international accords in which México is participating. In 2004, México and Europe signed an agreement on Scientific Cooperation and Technology. This agreement allows the participation of Mexican research centers within the *Programa Marco de Desarrollo Tecnológico de la Unión Europea 2002-2006* (Program for Technological Development of the European Union). Nanotechnology is a priority theme. There is also a bilateral agreement ("PROBICYT") in science and technology to strengthen and promote the creation of a national system of innovation, improve both human resources and infrastructure and to endorse competitiveness. In addition, México, together with other Latin American countries, participates in programs such as @Lis (Information Society), AL-Invest (Investments), ALBAN (Education) and Urbal (Urban Development) (Berlanga, 2004). NANOFORUMEULA, on the other hand, is a project on Nanotechnology R&D. The following partners are involved in the consortium: The University of Twente in Holland, the Superintendent of the Franca Zone of Manaus (SUFRAMA) in Brazil, the CEA-LETI-MINATEC in Grenoble, France, the Fraunhofer IWS Institute of Dresden in Germany, the Universidad Autónoma de Madrid in Spain and the IPICyT from México. This project shows that the European Union is interested in encouraging long-term relations between European institutions and their counterparts in Latin America (Suframa, 2007). In addition, the Inter-American Collaboration on Advanced Materials ("CIAM") is an institutional program created in 2002 to support research collaboration. Institutions from Argentina, Brazil, Canada, Chile, Colombia, México, Trinidad and Tobago, Jamaica and the U.S. are members of this organization. Several Mexican researchers have received grants to foster nanotechnology research.

2. Collaboration with the United States

The association between México and the U.S. operates in three main areas, all focusing on different forms and connections. These main areas include the scientific-academic association, the political-business interests and the scientific-military accords.

The role of FUMEC in this regard has been of increasing importance. George E. Brown Jr., the man behind the creation of the Office of Science and Technology Policy in the U.S. executive branch (created in 1976) and recognized for his position regarding the development of science oriented to satisfy social needs, published an article in 1998 with other scientists stating that most of the agreements on scientific collaboration signed by the U.S. only embodied diplomatic purposes with no further interests for the U.S. These agreements lack funding or follow-up associated with the implementation of the projects. The only exception, in his view, was FUMEC (which has been operating since 1993), because its research has focused on the treatment of water and health issues along the U.S.-Mexican border since the beginning. Brown saw FUMEC as an example of scientific cooperation (Brown, *et al*, 1998). After thirteen years it continues to connect U.S. and Mexican institutions, especially the ones alongside the national border. FUMEC is trying to integrate nanotechnology research between Mexican and U.S. industries. One of the main activities of FUMEC, with the Ministry of Economy (2001), is to facilitate the design, development, packaging and commercialization of MEMS/NEMS (Micro- and Nano-Electro Mechanical Systems). To this end, it has created the MEMS Design Center Network where 11 Mexican higher education institutions cooperate to design MEMS/NEMS, to develop industrial projects and to strengthen related academic programs. Another important FUMEC action was the creation of the MEMS Productive Articulation Center in 2004 to facilitate the collaboration between industry, academy and decision makers in order to develop new products and businesses. A third action was the creation of the Network of Innovation Laboratories, where all the partners have a specific role to play. The MEMS/NEMS prototypes are developed by UNAM and by UACJ, the manufacturing takes place in the INAOE laboratory in Puebla and the packing takes place in the UACJ in Chihuahua.

FUMEC also played an important role in the implementation of the Binational Sustainability Laboratory ("BNSL"), a not-for-profit and non-governmental organization that fosters business partnerships along the border. It came into existence in 2005. Among the main partners of BNSL are the Sandia National Laboratories, which are military laboratories based in Albuquerque, New México. They work under the Advanced Concepts Group philosophy with the main objective of fostering sustainable development in the border region, reducing stress, increasing local capabilities and expanding business. The strategic areas of work include MEMS Packaging to support the Paso del Norte Packaging Cluster regarding

R&D and commercialization, energy and advanced materials in order to decrease costs within the border, and water, with technical developments appropriate to the region. In all cases, several scientific institutions from México participate, such as UACJ, the ITESM and CIMAV together with U.S.-based enterprises. In addition, FUMEC has become an important collaborator in various workshops on nanotechnology, specifically in the agreements regarding academic exchange and other *ad hoc* activities. In recent years, Canadian representatives have also become part of the meetings, converting the workshops into trilateral activities (FUMEC, n/d).

Other foreign institutions also have collaboration agreements with Mexican institutions. The International Center for Nanotechnology and Advanced Materials ("ICNAM") is a consortium emerging from a previous agreement between the UT-Austin and CIMAV, signed in Chihuahua in 2003. The purpose of this accord is to promote bi-national research and the exchange of faculty, researchers and alumni. The Mexican centers and universities involved in the project are UASLP, the ITESM, UNAM, the UANL, IPICyT, CIQA, CINVESTAV and CIMAV (UTexas-A., n/d).

For its part, CIMAV signed an agreement in 2005 with the University of Albany College of Nanoscale Science and Engineering at Albano NanoTech to collaborate on nanotechnology research and on nanoscience education. The agreement is focused on specific research in optoelectronics, nanophotonics, chemical and biological sensors, molecular and carbon nanostructures, nanoparticles and computer simulation, scale-modeling of nanostructures and nanosystems (Azonano.com, 2005).

CIMAV is also the headquarters, since 2004, of the Consortium for Projects in Nanotechnology, which is part of the national System of networks and research centers of CONACYT. IPICyT, CIQA, CICESE, and INAOE are members of this consortium along with several enterprises (Chihuahua Cement, Peñoles Mining Group, Delphi, Lexmark, Mabe and Cydsa) (CIMAV, 2004; CONACYT, 2006).

Texas, meanwhile, is trying to promote itself as a leader in the application of nanotechnology. To this end, it has several associations. One of them is the Strategic Partnership for Research in Nanotechnology ("SPRING"), a network between UT-Austin, UT-Dallas, UT-Arlington, Rice University in Atlanta and the Air Force Research Laboratory in Dayton, Ohio. Related to this partnership, we find other consortiums such as "Nano at the Border," where several units from the University of Texas participate (Arlington, Austin, Brownsville, Dallas, and Pan American). It was created to facilitate academic exchange and to share infrastructure related to the research of nanotechnology like the Center for Nano and Molecular Science and Technology of UT-Austin. Another important objective of "Nano at the Border" is to include students and human resources from the Hispanic community (CNM, n/d) These consortiums and partnerships have been facilitating the creation of new agreements with Mexican universities directly and via CONACYT. This is the case for the agreement signed between ICNAM and CIMAV in Chihuahua as previously mentioned and the one between UT-Dallas, using its

NanoTech Institute, and the University of Guanajuato. These last two have created a workshop entitled "Nanoscience for Advanced Applications: At the Crossroads of Disciplines" (UTDallas, 2006).

One of the most promising contacts in science and engineering between academics and students from Latin America and the U.S. is the Pan American Advanced Study Institutes ("PASI") project:

... [PASI] is a jointly supported initiative between the Department of Energy (DOE) and the National Science Foundation (NSF). Pan American Advanced Studies Institutes are short courses of two-to-four weeks duration, involving lectures, demonstrations, research seminars and discussion at the advanced graduate and post-doctoral level. PASIs aim [is] to disseminate advanced scientific and engineering knowledge and stimulate training and cooperation among researchers of the Americas in the mathematical, physical, and biological sciences, and in engineering fields (National Science Foundation, n/d).

In 2001, Costa Rica held the first PASI meeting dedicated to nanosciences (physics and technology at the nanometer scale) (Ulloa, 2002). At least eight other PASI meetings about nanotechnology have taken place across Latin America. México took part in many, if not all of them, with presenters. These workshops create friendly environments where both students and academics can meet and exchange ideas regarding nanotechnology.

The political-business interests are present in the creation of high technology industrial parks. The idea is to provide the infrastructure and general conditions to allow national and transnational enterprises to open their doors, supported by research centers on high technology. The scientific and technological parks are centers to foster innovation. The success of these parks in México depends on reversing the exodus of manufacturing enterprises, which has been affecting the economy for the past decade. Costs have declined worldwide due to several technical advances in telecommunications, storage systems, transportation and the reduction of regulations. This has encouraged U.S.-based enterprises to move to South-East Asia. That trend includes the mobility of qualified personnel and most activities related to prototype design and, sometimes, the entire production process. At the same time, China, Thailand and Singapore have increased the production share of the manufacturing industry within their Gross National Product ("GNP"), while that share has decreased in the U.S. and México (Hung & León, 2005). This tendency contradicts the creation of R&D industrial parks and puts them at risk. Moreover, these circumstances add more pressure to scientists and technicians who, due to the lack of opportunities, migrate to other countries. The lack of scientific training at the basic education, high school and university levels reduces the possibility of obtaining nanotechnology-related positions. A basic but comprehensive training in science and math is essential to encourage several countries to jump from underdevelopment to development (e.g., South Korea), a possibility that México is not realizing[4]

The Silicon Border Development Science Park is portrayed as the first high-tech park specializing in nanotechnology R&D in Latin America. Located in Mexicali, Baja California Norte, it covers a 400-hectare area (Presidencia de la República, 2006). Its main purpose is to encourage the formation of supply chains for the semiconductor industry and other related areas. The project began in 2006 and is expected to be completed in ten years (TMC.net, 2005; Silicon Border, 2006).

The State Government of Puebla is trying to create a high-tech park in Huejotzingo. It is expected that this cluster would offer spare parts and supplies for the medical industry and for the automobile sector (García, 2007). INAOE also operates there, building the National Laboratory of Nanoelectronics. It is expected to have a top class clean room thanks to the donation by Motorola, in 2004, of a complete manufacturing line of integrated circuits (Calleja, n/d).

The State Government of Nuevo León has been building the Research Park for Technology Innovation since 2005. This park is one fraction of the project called *Ciudad del Conocimiento* (City of Knowledge). The plan is to attract the most important centers for research and education and convince them to set up shop in Monterrey. The UANL participates in this project with the Center for Innovation, Research and Development of Engineering and Technology. One of the laboratories, included as part of this center, is the Laboratory of Nanotechnology and Nanosciences, and there are other research institutions that are interested. For instance, CONACYT is taking the Engineering Center for Industrial Development and CIMAV to Monterrey, the ITESM is taking its Research Center for Strategic Design, the UAEM will open a center specializing in advanced packaging, IPN will be present with CINESTAV, the Institute of Water of Nuevo León will be present and several software enterprises will form a cluster there (Monterrey, 2006).

The Paso del Norte MEMS/NEMS Packaging Cluster intends to create a technological corridor between Albuquerque, NM, and the city of Chihuahua in México. In between lie the cities of Ciudad Juárez and El Paso, with the UACJ and UT-El Paso playing a key scientific role in this cluster. This cluster includes research centers, enterprises and the Sandia Military labs. It also has support from FUMEC.

There is one military agreement that stands out. In 2005, the Security and Prosperity Partnership of North America ("SPPNA") treaty was signed between México, the U.S., and Canada. It includes R&D in several areas, including nanotechnology, under a framework influenced directly by the military (SPPNA, 2005; González Amador, 2006).

4 In a meeting hosted by the World Bank in February 2007, the President of the Bank urged developing countries to support science, but said cautiously,"[t]he current danger lies in promoting policies that see S&T as *drivers* of social progress and economic development, rather than components of innovation programmes in which other factors—from regulatory policy to education and training—are just as important." *See* David Dickson, *Investing in Science: A Cautionary Tale*, SCIDEV.NET (Feb. 22, 2007) http://www.scidev.net/Editorials/index.cfm?fuseaction=readEditorials&itemid=211&language=1last visited April 22, 2007).

In April 2004, the Navy and the U.S. Air Force hosted an event in Washington, D.C., called the *Latin America Science & Technology Forum*, with the purpose of "increasing the U.S. leadership's awareness of the progress of Science and Technology ("S&T") in Latin America." (ONRG, 2004a). Top representatives from civil institutions related to S&T from Argentina (Vice-Director of CONICET), Chile (Director of FONDEF-CONICYT) and México (Director of Scientific Research of CONACYT) presented the status of S&T in their respective countries. This is just an example of the connecting ties between scientific interests and the military.

Another example of the military connection is the support from the U.S. Navy to nanotechnology-related research. This is coordinated by the U.S. International Technology Center, whose main objective is to "support the identification, acquisition, integration and delivery of foreign technology solutions to the war fighter to ensure technological superiority on the battlefield." (U.S. Army ITC-Atlantic, n/d). This center has divisions according to geographical area. Thus, the ITC-Atlantic covers Europe, Africa and one part of Asia, including one section of the former Soviet Union; the ITC-Pacific covers the rest of Asia and the southern cone of Africa; and, in 2004, the ITC-Américas was created in Santiago de Chile, to cover America and the Caribbean, including Canada (U.S. Army ITC-Atlantic, n/d b).[5]

The U.S. Navy, in association with the Air Force, held three international workshops in Latin America on multifunctional materials, a topic of interest for the U.S. Defense Department (NMAB, capítulo 3, 2003).[6] The first took place in Chile, in 2002. There was only one researcher from México present. The second was held in Huatulco, Oaxaca, México, in 2004, at which there were three researchers from México. The third was held in 2006 in Argentina (ONR, 2002, 2004, 2006).

Despite the little knowledge there is about the military accords, either bilateral or multilateral, it is a subject that should be closely examined since the "nanotechnology revolution" initiated in the U.S. was strongly linked to military research. Ever since the U.S. launched it's National Nanotechnology Initiative in 2001, between a third and a fourth of the federal budget for research has been di-

5 The mandate of ITC-Américas is: ". . .to foster cooperative relationships between the U.S. Army and private sector, university, and civilian government research and development (R&D) entities that result in leading-edge scientific and technological cooperation that benefit the civilian institutions and support the U.S. Army's current programs and future goals." *See* Int'l Division, U.S. Army Res., Dev. & Eng'g Command, *U.S. Army International Technology Center of the Americas Opens in Santiago,* REDECOM (2004), *available at* http://www.rdecom.army.mil/rdemagazine/200411/part_ITC.html (last visited April 22, 2007).

6 See NAT'L MATERIALS ADVISORY BD. ("NMAB"), MATERIALS RESEARCH TO MEET 21ST CENTURY DEFENSE NEEDS (2003). Multifunctional materials are materials that unite the double properties of structural integrity (durability, survivability, security) and at the same time, electrical, magnetic, optical, thermal, and biological functions. The core of these new materials is micro- and nanotechnology, and is one of the basic interests in R&D in Latin America and the United States Air Force. See Air Force Ofc. of Sci. Res. ("AFOSR"), *AFOSR Research Interests for Latin America, available at* http://72.14.253.104/search?q=cache:4fVmsg2SZygJ:www.prp.rei.unicamp.br/portal/mensagens/2005%2520AFOSR%2520Latin%2520American%2520Research%2520Interests.pdf+AFOSR+Research+Interests+for+Latin+America&hl=en&ct=clnk&cd=1 (last visited April 22, 2007).

rected to military research (EOPUS, 2005). This policy forces other countries to invest into nanotechnology for warfare (Altmann, 2006). In addition, most of the larger universities in the U.S. have projects financed by the Defense Department ("DOD") and some even have agreements with the military industry. Therefore, once the Mexican research centers are brought into the formula, the integration of military interests is facilitated. For instance, the cluster of Paso del Norte includes the Sandia National Laboratories of Albuquerque and the Bi-National Sustainability Laboratory. In this regard, even though military institutions can conduct civil research, is this just a sub-product of the research directly related to the military, according the Mansfield amendment of 1973?[7]

3. Final Considerations of the Nanotechnology Pathways in Mexico

The pathway followed by México in nanotechnology research is surprising, both for its fast growth in recent years and for the ambitious objectives it has undertaken. However, there are several issues worthy of further examination. Consider the following facts.

From the U.S. to Thailand and from Brazil to México, all countries justify the public funding directed to nanotechnology with the argument that it is urgent to increase competitiveness. This, they say, is to be done by using nanotechnology, as it promises to be the next industrial revolution. The world economy bases its success on technological innovation, which in turn puts countries that do not invest in technology in disadvantaged positions. In this context, nanotechnology appears to be a necessity more than an option. But competitiveness is not only the result of individualized efforts. To be competitive, it is necessary that someone else lose. This is the law of the market. The race between several regions and/or states in México to build scientific-industrial parks could increase the competition between them, thus increasing the possibility of failure and encouraging environmental degradation. In the absence of a national plan, could this increase intra-national competition and, as a consequence, weaken the international position of México?

Why would transnational enterprises like to set up shop in México? Geography can be an answer, but not necessarily the most important one. Perhaps it has something to do with the paucity of regulations and lax rules. In the U.S., the potential risks to health and the threats to the environment derived from nanoparticles are part of the political agenda. As a consequence, the costs for nanotechnology R&D might increase. It is likely that some enterprises will seek to avoid these costs by migrating to countries where these rules are nonexistent.

7 The controversial Mansfield Amendment of 1973 expressly limited appropriations for defense research (through ARPA/DARPA) to projects with direct military application

Is this condition a potential risk to countries such as México where there is no consideration about the possible environmental effects of the use of nanotechnology? Further, can the lack of regulations unbalance the possible positive benefits of nanotechnology?

Building high-tech scientific parks is not only a matter of infrastructure. If the projects are successful, the requirements for technical personnel and highly qualified human resources will increase. Even though there are several graduate programs in nanotechnology in México (IPICyT, BUAP, IMP, UANL, CIMAV, UNAM, UANL, CINVESTAV, etc.), the public budget directed to R&D has been decreasing in the last decade. Additionally, there is no proper training in math and science at the lower levels of the education system, which can affect enrollment in highly technical graduate programs in the future. In the U.S., Canada and Europe there is serious concern about the scarcity of scientists in the area of nanotechnology. Is it possible that México, with a scarce number of technical and scientific personnel, will be able to supply the demands of the scientific parks and the recently created research centers? Could the increasing number of partnerships and agreements, such as ICNAM, which allows Mexican students to pursue graduate studies in the U.S., be a threat to increase the brain drain from México to the U.S.?

It is clear that nanotechnology research in México is associated with the possibility of increasing competitiveness. It is also done to attract foreign capital. Both the increase of competitiveness and the attraction of capital are regulated by profit-making. Under current conditions in México there is no regulation or public discussion about the use of nanotechnology. Is it a latent risk to allow the development of nanotechnology without appropriate oversight? Could this exacerbate the prevailing internal inequity?

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Nanotechnology in Chile: Towards a Knowledge Economy?[3]

Introduction

Nanotechnologies are rapidly growing worldwide. Poor countries are also taking part in the development of this technological revolution. In Latin America, Brazil, Mexico and Argentina are the leading nations in the area; however there are other countries pursuing important efforts to develop nanotechnologies and nanosciences. Chile has several research projects underway across five universities.

The promotion of nanotechnology research is a strategy inserted in the paradigm of encouraging development via the knowledge economy. The World Bank, as the main institution promoting this paradigm, selected Chile as the pioneer to implement the Scientific Millennium Initiatives, which have supported some research projects related to nanotechnology.

In this chapter we analyze the development of nanotechnology in Chile within the framework of the paradigm of the knowledge economy and we question the sustainability of the Centers of Excellence. In addition, we elaborate on the weaknesses of using nanotechnology as a tool for development in Chile.

1. The World Bank's Promotion of the Knowledge Economy in Latin America.

In Latin America the promotion of nanotechnologies is associated with the reorientation of its economies to make them less dependent on crop exports, the mining industry and sectors linked to the exploitation of natural resources. The idea is to base the development process on what has come to be known as the Knowledge Economy. The transition from industrial economies to knowledge economies is happening already in developed countries such as the United States, the European Union and Japan. In general, experts use the percentage of high-tech manufactures being exported ? which presumably are the direct outcome of intense research and development (R&D)? to measure the advance of the knowledge economy. There are several industrial branches that structure the high-tech sector in an economy, such as aerospace, pharmaceuticals, computers, scientific instruments and electrical machinery. In 2004, 34% of overall exports in the United Sta-

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tes were high-tech manufactures; 24% in Japan, 34% in South Korea and Ireland. In Latin America, Argentinean high-tech manufactures make up to 8% of its exports, in Chile 5%, in Brazil 12% and in Mexico 21% (World Bank, 2006a). In the case of Mexico, the weight of maquiladora production and the strong intra-firm trade of US transnationals suggest that there is a need to be cautious in the analysis (Delgado & Invernizzi, 2005). There are other indicators used to show the degree in which a given country is incorporated into the knowledge economy, such as the KAM (Knowledge Assessment Methodology) of the World Bank. This indicator includes several variables like patents, access to education and telecommunications, institutional environment and others (World Bank, 2006b).

During the 1980s, the World Bank concentrated its efforts in economic liberalization. A part of that orientation involved closing the Department of Science and eliminating the position of Scientific Advisor of the World Bank. From the early 1990s there was a change of policy recognizing scientific research as the motor for development (Masood, 1999). The World Bank's *World Development Report 1998-1999* carried the subtitle *Knowledge for Development*, referring to the gap in knowledge between rich and poor countries. The basis for this change was the recognition that the economic liberalization implemented during the 1980s had not attained the anticipated results, but rather had increased the gap between rich and poor countries, and increased their foreign debt. In addition, the Bank pointed out that the patents regime (accepted by the World Trade Organization)[4] had not promoted private research in areas with a large impact on the development process, but with little return of profits, such as the so-called *neglected diseases* (i.e., in the case of drugs to treat malaria). According to the World Bank, in cases like this one, the public system should subsidize research (*Nature*, 1988). The Bank also showed concern for the extension of intellectual property rights beyond products, particularly to cover biotechnology achievements (Butler, 1988). The proposal from the World Bank, at the end of the 1990s, was to incorporate the topics related to innovation, science and technology and technological transfers, in policy implementation for achieving development in poor countries.

The development orientation towards the knowledge economy was not and has not been an exclusive paradigm of the World Bank. In Latin America, at the beginning of the 1990s, several countries achieved the implementation of the knowledge economy as an alternative path to development. The European Union has also been promoting the knowledge economy. Chile, for instance, and parallel to the agreements previously signed with the World Bank, became part of another effort with the European Union in 2001. The objective was to encourage, develop and facilitate R&D activities between Chile and the European Community, in

4 TRIPS (Agreement on Trade-Related Aspects of Intellectual Property Rights) was created to guarantee patent protection of foreign trade operations. TRIPS sets down minimum standards for many forms of intellectual property regulation. TRIPS also established a legal system and mechanism for dispute settlement, including sanctions, for countries that do not comply with the legislation.

scientific and technological areas. The agreement was articulated within the framework of a flagship program which identified areas with strategic priority, such as nanotechnology (SICID, 2002). In 2006, within MERCOSUR, Chile signed a declaration to create the *Espacio Regional de Investigación en Ciencia, Tecnología e Innovación* (Regional Space for Scientific Research, Technology and Innovation) (CONICYT, 2006 May).

In order to confront the challenge of implementing knowledge economies in underdeveloped countries the World Bank followed the strategy of creating nuclei of excellence in research. At the end of the 1990s, the World Bank and other institutions created a global network of Millennium Initiatives. These initiatives would become centers of excellence in research in underdeveloped countries with the purpose of encouraging Science and Technology (S&T) under equal conditions of infrastructure and resources as exists in research centers in the developed countries (Macilwain, 1998).

2. Nanotechnology and the Centers of Excellence in Chile

Nanotechnologies are part of a technological branch that is growing worldwide and are associated with both the knowledge economy and the innovation paradigm.[5] The investments in nanotechnology have been growing steadily since 2001, particularly after the United States launched its well funded research program (*National Nanotechnology Initiative*). Later, many other countries followed the example. Lux Research (2006), a company that investigates the investment and the commercialization of nanotechnology in the world, estimated that in 2005, 9.6 billion dollars were allocated to R&D in this area. In 2005, private investment in nanotechnology R&D surpassed public funding. The latter indicates that corporations and enterprises doing research in this area judge their investments according to the profits they will attain. Lux Research estimates that, even though the nanocomponents market is still small, in 2005, $32 billion were sold, doubling the figure from the previous year, and for 2014, the estimate is $2,6 trillion.

In Latin America, Brazil, Argentina and Mexico are countries where nanotechnology research is underway (Foladori, 2006). In 2001, Brazil created several networks in nanotechnology research. In 2004, it announced the Nanoscience and Nanotechnology Program, within the framework of the *Plano Plurianual de Desenvolvimento 2004-2007* (The Multi-Year Plan for Development 2004-2007)

5 For the purpose of this article the term nanotechnologies will be used to include the concept of nanoscience. The Royal Society & The Royal Academy of Engineering (RS&RAE) (2004) defines both terms: “We define Nanoscience as the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale; and nanotechnologies as the design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanometer scale.” (Summary, 2)

(MCT, 2004a, 2004b). In 2005, the Argentinean government created the Argentinean Foundation of Nanotechnology. In Mexico, on the other hand, there are several laboratories doing nanotechnology research, including the construction of several high-tech parks where nanocomponents have a strong presence (Foladori & Zayago, 2007).

The interest of the Chilean Government to use technological innovation as a tool for development has been present at least since the beginning of the 1990s. Between 1992 and 1995 it implemented the *Programa de Ciencia y Tecnología* (the Science and Technology Program) with the support from the Inter-American Development Bank. In the following years, it created the *Programa de Innovación Tecnológica* (the Program for Technological Innovation) (1996-2000). Both programs were followed, since 2001, by a program called *Chile Innova* (Chile Innovates), which was the program for technological innovation and development of the Chilean Ministry of Economy. It concluded at the end of 2005 (Chile Innova, 2006). The main objective was to increase international competitiveness by supporting innovation and technological development in strategic areas. To secure this purpose, *Chile Innova* defined five strategic areas to be developed: Technological Perspectives, Information Technology and Communications, Biotechnology, Clean Production Systems and Quality Standards.

During the government of President Ricardo Lagos (2000-2006), the World Bank financed seven projects in the country, allocating US$215 million for six central projects. Some examples are the program of *Tecnología e Innovación* (Technology and Innovation) (World Bank, 2006) and the *Programa Bicentenario de Ciencia y Tecnología (PBCT)* (Bicentennial Program of Science and Technology) (2004-2010) which is an initiative worth US $100 million, equally financed by the Chilean Government and the World Bank in two phases of three years. The main focus is on the development of a knowledge economy is stated by the same program: *"The purpose of PBCT is to support and direct the process towards a society and an economy based on knowledge, by investing in science and innovation areas linked to the business sector in the country and the world wide networks of science and technology" (CONICYT - Banco Mundial, s/f.a)*. This idea falls under the presumption that S&T would allow Chile to be competitive with the world (CONICYT, 2005).

In 1997, the *Comisión Nacional de Ciencia y Tecnología* (CONICYT) (National Commission of Science and Technology) opened its Centers of Excellence via the *Programa Fondo de Investigación Avanzada en Áreas Prioritarias* (FONDAP) (Program of Advanced Research in Strategic Areas). These centers, in addition to maintaining a high level of excellence, offer Doctorate Programs evaluated by CONICYT. The purpose is to encourage the formation of links between the scientific and technology sector and businesses. The idea is to orient research towards innovative processes, products or services to be commercialized and also to facilitate technological transfers amongst enterprises (FONDAP, s/f). This is similar to what in later years the Ministry of Planification and the World Bank launched as the Millennium Initiative; however the two programs are not integrated. The FONDAP supplies funding to a program conducting nanotechnology research via the creation, in 1999, of the *Centro para la Investigación Interdisciplinaria Avanzada en Ciencia de Materiales* (Center of Advanced Interdisciplinary Research in Science of Materials) in the Universidad de Chile. The following chart shows the centers created by FONDAP.

FONDAP Centers of Excellence and Nanotecnology Presence

Date	Name of the Institute or Nucleus	Headquarter
1997-1998	• Center of Mathematic Modulation • Center of Cellular Regulation and Pathology	• Universidad de Chile • Pontificia Universidad Católica de Chile
1999	• *Center of Advanced Interdisciplinary Research in Science of Materials* (Research on Nanomaterials)	• Universidad de Chile
2001-2002	• Center of Pacific Oceanographic South-Oriental • Center of Advanced Studies in Ecology and Biodiversity • Center of Astrophysics • Center of Cellular Molecular Studies	• Universidad de Concepción • Pontificia Universidad Católica de Chile • Universidad de Chile • Universidad de Chile

Source: Own elaboration from Sabater Villalba, 2004.

The Center of Advanced Interdisciplinary Research in Science of Materials of the Universidad de Chile is researching nanotechnology with the intention of developing new patents to commercialize, particularly with copper as a base (FONDAP, s/f). Between 1999 and 2003, FONDAP allocated 15.9-million Chilean pesos, while in the same period the Millennium Initiative of the World Bank supplied 18.4 million Chilean pesos (Contreras et al, 2006).

Another program of the CONICYT associated with the financing of individual projects, the FONDECYT, included nanotechnology and it is estimated that more than 37 projects in this area were financed, bringing benefits to researchers working at 6 public universities and one private (Fajardo, s/f).

The Scientific Millennium Initiative, encouraged by the World Bank, was implemented in Chile as the prototype to be further developed in other countries.[6] In 1999, the Chilean Government created the National Commission of Millennium Initiatives, with the purpose of developing research and scientific capacities and, of course, developed further connections with the World Bank (DORCH, 1999). In consequence, the World Bank granted a loan of US $5 million for the first stage of two-and-a-half years on top of the US $10 million provided by the national government (ICM, s/f.a). The objectives of the Millennium Scientific Initiatives (MSI) were:

6 Venezuela, Mexico and Brazil later initiated similar programs.

…encourage scientific research, taking advantage of and stimulating the best talent in the country, as key factors for encouraging sustainable socio-economic development. The Program objective is the formation of Centers of Excellence to stimulate the creation of Scientific Institutes and Scientific Nuclei, under the principles of competitiveness and transparency. These centers will push the boundaries of science by training scientists, will contribute to the dissemination of new knowledge using educational programs and will contribute to the establishment of links between the productive sectors and other institutions (ICM, s/f.a).

It can be argued that instead of adjusting the research agenda according to the interests of a national plan for development, the program identified Chilean talents within outside of the country to support their particular research agenda. This scientific policy seems to be elitist, but it was based on the idea that whatever direction innovation can take, at the end it will increase competitiveness to guarantee development. Other objectives included attracting talents from overseas and avoiding brain-drain.

The pilot policy suggested by the World Bank and implemented in Chile is a *top-down policy*. Some of the prominent scientists established centers of excellence for themselves. The idea thereafter was to wait for them to form partnerships with the private sector to foster productive innovation. Although the spirit of the plan was to create the conditions for the researchers to stay in Chile and not migrate, it is debatable whether this could be achieved in enclaves of excellence with short support and without a concurrent basic educational reform effort to nourish and allow the replication, in the long-term, of a path for technological innovation. These enclaves of excellence would have to survive in a country where only 0.6 % of the GDP is meant for S&T; a very low figure, only a few decimals above México's commitment and clearly inferior to the Brazilian and the Venezuelan budget for S&T in the Latin American context. It was clearly inferior to the budget supplied for S&T in developed countries and some others that have encouraged innovation in previous years:

In 2004, Chile invested 0.68% of GDP in R&D. South Korea invested 2.4% when it had a GDP per capita similar to the one in Chile, or Ireland (1.3% of GDP) or Slovenia (1.4%). At the same time, compared to the funding invested in R&D in developed countries, the difference is even higher: Israel is at top of the ranking with 4.9%, Sweden comes second with 4%, then Finland with 3.5% and the US with 2.6%. As a conclusion, with the exception of Hong Kong, all countries similar or more developed than Chile invest more in R&D, as a fraction of the GDP, since their development was similar to the one in Chile (CNIC, 2007).

In the case of Chile, the lack of infrastructure and human resources were the justifications supporting the implementation of the Millennium Initiatives. In the first stage of the MSI three institutes and five nuclei were created. One of them was created to perform nanotechnology research (Physics of Condensed Materials) headquartered in the Universidad Técnica Federico Santa María (ICM, s/f.a).

During the second stage, five research nuclei were created, but none of them oriented towards nanotechnology research. For the third stage, inaugurated in 2002 and implemented in 2003, a new project related to nanotechnology research was approved. It was headquartered at the Universidad Andrés Bello (Material science and nanotechnology, organic physiochemical and theory of densities) and the program of Physics of Condensed Materials was extended for another three years (ICM s/f.b). The next chart provides a summary of the initiatives in chronological order, highlighting the ones related to nanotechnology research;

Scientific Millenium Initiatives. Chile 1999 -2006 [7]

Year	Number of Institutes or Nuclei created	Name of the Institute or Nuclei	Headquarters
1999	3 Institutes 5 Nuclei	• Physics of Condensed Materials	• Universidad Técnica Federico Santa María
2001	5 Nuclei	------	-----
2002	3 Institutes	• Quantico Applied Mechanics and chemical informatics (Nucleus)	• U. Andrés Bello
2003	3 Institutes 8 Nuclei	• Physics of Condensed Materials (Nucleus- renewed)	• U. Técnica Federico Santa María
2004	3 Institutes 12 Nuclei	-----	-----
2005	3 Institutes 15 Nuclei	-----	-----
2006 (increased with "Royalty Law Funds"[8]	5 Institutes 17 Nuclei	-----	-----

Source: ICM, 2006; ICM s/f.a; ICM s/f.b).

The MSI's provided marginal support for nanotechnology development; they oriented their research efforts toward other areas, such as biotechnologies and biology. Areas that had a stronger research tradition received greater support in Chile (however it is possible that in the area of biotechnology they had some projects dealing with nanobiotechnology not considered in the previous chart). Despite the lack of support, the only two research projects dealing with nanotechnology provided an important framework for a country where the support to this kind of project was scarce. Although the spirit of the MSI's was to create institutes and research nuclei able to compete with their counterparts in developed countries, in practice they were under-funded. These projects had a medium budget of US

7 The information on Nanotechnology is approximate. The criteria employed were keyword indicators in the title or project description (nanotechnology, nanosciences, nanoscopic, nanostructured, nanocapsules).

8 The resources that were coming from the Royalty Law to encourage innovation and competitiveness increased in 100% in 2007. This will allow the financing of another five institutes and 17 research nuclei in the country (MIDEPLAN, 2006).

$290,000 for three years but with the possibility of just one renewal, which in the long term weakened the feasibility of the projects (Angel, 2003). Some extra resources came from the "Royalty" Law approved in 2006. This regulation imposes taxes over the exploitation of natural resources used for scientific innovation. This would increase the resources used in the implementation of new projects and the development of new research nuclei.[9] However, it is worth mentioning that the total amount of resources are miniscule in relation to the size of the economy, as pointed out by the Chilean economist and member of the council of the Millennium Initiative, French Davis (2006).

As part of the Bicentennial Program of Science and Technology, the "*Anillos de Investigacion de Ciencia y Tecnologia*" (Research Rings of Science and Technology) were financed for three years. These rings are research networks formed by universities and research centers. Calls for grants were organized in 2004 and 2005 but only in 2006 some research rings doing nanotechnology research were approved, as illustrated in the following chart;

"Rings" oriented to nanotechnology research and approved by The Bicentennial Program of Science and Technology in Chile (2006)

	Name of the ring	Associated University
University U. de Chile	Molecular Simulation of Nanomaterials and Biological Experimental Systems	Universidad de Talca
U. de Santiago de Chile	Magnetism: From Nanoscale to Macro scale	Univ. Técnica Federico Santa María Universidad de la Frontera. Pontificia Pontificia Univ. Católica de Chile
U. Técnica Federico Santa María	Multidisciplinary Research of Hybrid Nanostructures	Universidad de Valparaíso.
U. Técnica Federico Santa María	Subatomic Research Center	Pontificia Univ. Católica de Chile Universidad Austral de Chile

Source: CONICYT – World Bank, s/f.b.

Within the framework of the Bicentennial Program of Science and Technology several "*Talleres de Articulacion*" (Articulation Workshops) were implemented to motivate academics and students to pursue subjects related to technology and innovation. At the end of 2005, two workshops dealing with nanotechnology were opened. The first was organized in May 2006 by the Universidad Técnica Federico Santa María in partnership with several universities (CONICYT – Banco Mundial, s/f c). The second was organized by the Pontificia Universidad Católica de Chile and the Universidad de Santiago de Chile, and the participation of some others in October 2006 (CONICYT – Banco Mundial, s/f d).

9 In order to allocate the resources coming from The Royalty Law, the National Council of Innovation and Competitiveness was created. The name reflects the main interest of Chilean S&T policy: international competitiveness. It remains to be seen if competitiveness can encourage development, understanding it as the reduction of poverty and inequality.

3. Nanotechnology Research Areas in Chile

Zumelzu (2006) offers a revision of the current research projects in nanotechnology in Chile. He identifies several main institutions: the Universidad de Chile, the Universidad Técnica Federico Santa María; the Pontificia Universidad Católica de Chile and the Universidad de Santiago de Chile. The following chart provides a summary of the institutions, the research projects and the sources of funding;

Research Groups in Nanotechnology and Main Research Topics for Chile

Universities	Topics	Fund
Universidad Técnica Federico Santa María. Red con varias otras universidades	• Physics of Condensed Materials (Magnetism in low dimensions)	ICM (1999-2005)
Centro para la Investigación Interdisciplinaria Avanzada en Ciencia de los Materiales. Universidad de Chile.	• Quantic materials to produce confined effects detectable in the ionic, electronic and photonic properties. • Surface characterization and preparation of nanodusts deficient in oxygen via hydrogen condensation • Thin films working in the superficial dispersion of electrons over the transport mechanisms of electricity surrounded by rough surfaces • Production of Nanoparticles of copper to elaborate high conductivity polymers • Magnet Nanoparticles to treat cancer and Alzheimer's	FONDAP 1999…
Pontificia Universidad Católica de Chile	• Electrical conductivity in thin films of copper and palladium under oxidation • Magnetic exchange analysis	FONDECYT
Universidad de Santiago de Chile	• Nanocristaline evolution and micro structural research during the processes of mechanic alloying • Research of the phenomena and processes of the transport of fluids at the micro and nanoscales in non-conventional systems • Transport of micro and nano particles using biological systems • Transport of fluids and heat with microelectronic and nanocomponents • Transport and characterization of fluids in arteries and brain aneurysms • Characterization of nano fluids in the interphase between the hard disk surface and the reading/writing component of a high speed storage systems • Nanofluids and heat transfer at the nanometric scale, artificial organs and chaos theory in fluid mechanics	
Universidad de Concepción	• Advanced compounds and polymers, such as the production of Nanoparticles of copper for the industry particularly to be used in the energy sector; the creation of new nanostructure surfaces based on cellular membranes and their biological and chemical effects; nanocoloidal particles and research of new materials • Synthesis and application of organic compounds, development of macromolecular matrix, including metallic Nanoparticles	

Source: Data taken from Zumelzu (2006) with addition from Correa (2005), CONICYT (2005, March); Universidad de Santiago (2007), and own data.

Despite the number of institutions and projects created to support nanotechnology development in Chile there were not many researchers working in the field. Guzman (in Rojas, 2006) estimates that today 15 researchers are directing nanotechnology in Chile. Although this number does not take into consideration the scientists working in the area of nanobiotechnology, the fact of the matter is that the number of researchers working with nanotechnology in Chile is very small.

Surprising, however, is he lack of information regarding the creation of programs looking at the possible risks of using nanotechnology, as well as the social and economic impacts of applying it. This is particularly important if we consider that more than 80% of the Chilean research is conducted in public institutions. Social sciences seem to be absent in the discussion about chilean nanotechnology development.[10]

4. The Dark Side of Nanotechnology in Chile: The United States' Military Presence

Another kind of nanotechnology research in Chile is the one led by US military interests. The US interest in developing S&T in Latin America is explicit and despite much of the information about the financial and human resources is available on line via the internet; direct contacts are always made to facilitate future collaborations. For that reason, in April 2004, the US Navy and the Air Force held a forum in Washington D.C., called *Latin America Science & Technology* Forum, with the main purpose of "increasing the U.S. leadership's awareness of the progress of Science and Technology ("S&T") in Latin America"(ONRG, 2004a). Top representatives from civil institutions connected to S&T from Argentina (Vice-Director of CONICET), from Chile (Director of FONDEF-CONICYT) and from Mexico (Director of Scientific Research of CONICYT) presented the status of S&T in their countries. It gave the impression that top officials had the obligation of informing the US military about the condition of S&T in Latin America. At any rate, these schemes of collaboration have been complemented by official visits to Latin America. At the end of March 2002, the Associated Director of the International Area of the Naval Research Office of the US visited la Universidad de Concepción in Chile with the purpose of identifying the research areas that could be integrated inside an agreement (Panorama en Internet, 2002).

The US Armed Forces have, at least, 3 branches financing scientific research (including nanotechnology) in public, private universities and research centers, in many countries: Army, Navy, and Air Force.[11] These three branches work in part-

10 ...despite the lack of analysis about the social and economic impacts of nanotechnology, as well as the potential risks of using in this technology. However, there is a law presented in 2006 against the importation of products containing nanocomponents. (Navarro 2006).

11 In 1940, just before the United States entered into the Second World War, U.S. President Franklin Roosevelt

nership with the International Technology Centers to execute research programs on S&T. To organize this, there are centers such as the ITC-Atlantic, headquartered in London to cover Europe, Africa and Asia, including the area of the former Soviet Union; the ITC-Pacific headquartered in Tokyo to cover the rest of Asia and the Southern part of Africa.

In 2004, the ITC-Americas headquartered in Santiago de Chile is created to cover Latin America and the Caribbean, including Canada (U.S. Army ITC-Atlantic, s/f b). Equally to the other regional ITCs, the ITC-Americas in Chile has the objective:

...to foster cooperative relationships between the U.S. Army and private sector, university, and civilian government research and development (R&D) entities that result in leading-edge scientific and technological cooperation that benefit the civilian institutions and support the U.S. Army's current programs and future goals." (International Division U.S. Army Research, Development and Engineering Command, 2004).

The direct support received by research projects working with nanotechnology in Latin America was never delayed. According to the web page of the US Navy, since 2004 it has been financing a joint project between the Atomic Center of Bariloche in Argentina, the University of Michigan, Brown University and the Naval Research Laboratory; another project was created in the same year with collaboration of the Universidad de São Paulo in Brazil (ONRG, 2004b). However, in order to finance these research projects, the US Army had to first know which scientists could meet its needs. For this reason, the US Navy, in association with the Air Force, held three international workshops in Latin America. The main focus of these workshops was on one topic of strategic importance for the US Defense Department: multifunctional materials (NMAB, chapter 3, 2003). The multifunctional materials are materials that have at least two particular properties. On one hand they can develop structural integrity (durability, survivability and security) and on the other, different kinds of new functions such as electrical, magnetic, optical, biological and others. The basic tools for developing these new materials are provided by micro and nanotechnology: this is why the US Navy and the Air Force have so much interest in shaping R&D in Latin America (AFOSR, 2005a).

The multifunctional implies coupling between structural performance and other as-needed functionalities such as electrical, magnetic, optical, thermal, biological, and so forth. Structural integrity includes durability, survivability, reliability, and maintainability. This program thus focuses on developing and applying multifunctional mechanics principles and design methodology based on physics, chemistry, biology, and artificial intelligence to model and characterize the pro-

created the OSRD. The purpose of this office was to orient research to develop the military needs and armament. Traditionally, the military system used to encourage engineering and production, but not basic research. The OSRD became the first official governmental office to take care of basic research. For the first in US history, the relationship between S&T and the military interests was clear (White, 2002).

cessing and performance of multifunctional material systems and devices at multiple scales. (AFOSR, 2005b).

These seminars were organized by Latin-Americans working at US-based Universities together with other US citizens in order to facilitate contact with Latin-Americans. Initially, most of the participants were from the US, but the presence of Latin-American scientists increased in the following seminars. The first seminar was held in Pucon, Chile, in October 2002, and from the 44 participants 3 were from Argentina (Centro Atómico Bariloche y Universidad de Buenos Aires), 2 from Brazil (Laboratório Nacional de Luz Sincrotón y Pontificia Universidad Católica de Río de Janeiro), 1 from México (Centro de Investigaciones en Materiales Avanzados del Instituto Politécnico Nacional) and 3 from Chile (Pontifica Universidad Católica de Chile y Universidad Técnica Federico Santa María). In short, 9 Latin-American scientists overall. The second was held in Huatulco, Oaxaca, México, in 2004. From the 35 participants, 12 were coming from Latin America; 5 from Argentina (CAB, UBA, Centro Atómico Constituyentes y Comisión Nacional de Energía Atómica), 1 from Brazil (LNLS), 3 researchers from México (CINVESTAV-IPN, Universidad Nacional Autónoma de México), 2 from Chile (PUC-Chile y UTFSM) and one from the Universidad del Valle of Colombia. The third seminar was held in March 2006 in Bariloche, Argentina, where 35 scientists met: 6 from Argentina (CAB, CNEA, CAC and UBA), 3 from Brazil (LNLS, Universidad de Estadual de Campinas-Física and the Universidade Federal da Bahia), 2 or 3 from México (CINVESTAV-IPN and with the invitation but unconfirmed attendance of the Instituto Potosino de Investigaciones en Ciencia y Tecnología[12]) and one from Chile (Universidad de Chile) (ONR, 2002, 2004, 2006; U.S. Embassy Chile, s/f; Ulloa, 2004). This means that in the first meeting, less than a quarter of the participants were Latin-Americans. At the next meeting they made up one-third of the audience, but in all three seminars there was always at least one Chilean scientist.

The US military presence in nanotechnology research in Latin America has not been exclusively of military institutions encouraging S&T. There are broader possibilities to foster nanotechnology research that fell under different kinds of agreements such as the *Security and Prosperity Partnership of North America* (SPPNA) signed in 2005 by México, the US and Canada. This agreement encourages R&D in partnerships in areas such as biotechnology and nanotechnology, under a framework controlled by the US military (SPPNA, 2005). The US military presence is not reduced to the partnership between the civil sector and the military; there is also involvement from the Latin-American armed forces. An example of this would be the meeting held in Buenos Aires in June 2006, called "*The Contribution of Science and Technology to support Peace Keeping Operations and Disaster Relief Operation in Catastrophes*" where military experts from dif-

12 In this case both sources consulted did not match.

ferent countries such as Argentina, Bolivia, Brazil, Canada, Chile, Uruguay, Colombia, El Salvador, Mexico, Guatemala, Nicaragua, Paraguay, Peru, Uruguay, the Dominican Republic and Venezuela were present. The results went beyond what the title of this conference entailed, since it was agreed that in the future, conferences topics such as "the application of non-lethal technologies for crowd control; water purification and distribution; electric power generation and food preservation" were to be discussed (USARSO, 2006).

Final Reflections

Nanotechnology is a scientific area of rapid growth worldwide; many consider it as the basis for the next industrial revolution. It is possible that in the near future no country would be able to escape from the necessity of researching and developing this technology. Today, many countries argue in favor of investing public funds to develop nanotechnology in the search for increasing competitiveness. That is the case of Chile.

Despite all good intentions, there are several aspects to be taken into consideration in the case of Chile, such as the health risks and the environmental consequences of the potential use of nanotechnology. It is known that the small size of nanoparticles and nanocomponents makes them more reactive and mobile than any other components of regular size. In an article published by the British magazine *Nature* in 2006, 14 leading researchers in toxicology warned about the potential risks of the use of nanoparticles. They warned about the need to take into consideration the surface area, the chemical attributes of the surface, the solubility and of course, the size when researching and using nanoparticles because most of these aspects are not considered when scientists work with macro particles (Maynard, et al, 2006, 267).

Another area of concern is the commercialization of products containing nanocomponents that could change the international division of labor. This can, without any doubt, undermine the conditions of the working classes. On one hand, nanotechnology can reduce the amount of labor in many areas of production such as: the productive process, during the manipulation of the product, the storing process and during the transportation. On the other, because the substitution of natural resources will change the geographical requirements to open industries and in consequence the work force will be displaced in the search for jobs.

Another important area of concern inside the Chilean case is the one related to property ownership and patents. It is difficult to comply with the rules controlling nanocomponents and to fully obey the patents regime; particularly because most of these products are not considered under current regulations. In the US, there has been an increase in the number of trials dealing with nanotechnology patents. In addition, there is the issue of foreign trade agreements that make the dynamic more complicated to follow. In practice, all trade agreements have clauses that regulate property rights, but little has been researched about who gets the benefits and the obstacles imposed to patent registration under the legal framework of these agreements (Chimuris & Galindo, 2007). The justification to allocate public funds for nanotechnology development in Chile is the increase in competitiveness. However, the fact of the matter is that the production of nanocomponents is being centralized and is subordinated to the control of large multinational corporations (Científica, 2007). Underdeveloped countries must therefore be cautious about the possible role they would play in the international division of labor after developing and using nanotechnologies.

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Nanotechnology in Uruguay[4]

Introduction

This chapter is part of a larger effort to study the development of nanotechnology in Latin America and particularly in Uruguay.[5] This endeavor seeks also to understand the position of stakeholders with respect to the advantages, risks, and challenges brought about by these disruptive technologies. We describe the development of nanotechnology in Uruguay, and highlight the appropriateness of approaching technoscience considering ethical, legal, and societal implications (ELSI), including the economic impacts, and risks to health and the environment. This text begins with a discussion of the antecedents of the recent development of nanotechnology. A succinct overview of Uruguay's Science, Technology, and Innovation policy is presented in order to provide the context within which nanotechnology developed in Uruguay and found a place in the public agenda. Looking at the local dynamics allows for observing the catalytic role of certain actors in the process of linking Uruguayan nano-scientists, constituting the Group Nanotec Uruguay (G-Nanotec-Uy), and establishing regional collaborations.

The chapter considers ELSI, and proposes a number of alternative actions to generate opportunities for practitioners of nanotechnology, as well as basic considerations for the design of science, technology, and innovation policy in Uruguay concerned with nanotechnology. This study is based on interviews to qualified commentators, and archival review of the earliest news media that reported on nanotechnology in Uruguay

1. Background

Nanotechnology has broad application, reaching all aspects of human life. The novelty of nanotechnology is that matter exhibits different and new properties when it is manipulated in the scale of 1 to 100 nanometers. One of these characteristics is, for instance, greater sensibility, producing materials almost intelligent, i.e. highly sensitive and responsive to their environment. Another feature of nanotechnology is that it blurs the frontier of the living and the non-living given that it allows

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5 Nanotechnology refers here both to nanoscience and nanotechnology.

for inert nanoparticles and living organisms to be inextricable intertwined, or for living components to give life to artificial objects. These possibilities could become a reality in the near future. In order to illustrate one of the multiple realms of application of nanotechnology, we should comment the application for a patent by the Venter Institute, in July 2007 (application 20070122826, US Office of Patents and Trademark), claiming ownership to genome that brings to life *a synthetic organism able to grow and reproduce*. The Venter Institute had previously filed for the same patent at the World Intellectual Property Organization (application WO200047148) in April 2007 (ETC Group, 2007). This is a bacteria built from synthetic ADN; the allegedly is the first living being artificially created in a lab. The patent would grant a monopoly to the Venter Institute over any synthetic life form with at least 55 of the 101 *essential genes* they claim to have identified. This example illustrates how research in nanotechnology implies ethical considerations as profound as those of the creation of life. No doubt, reminiscent of the Chakrabarty case in the eighties,[6] and Dolly, the cloned sheep, in 1997.[7]

The discussion of the ethical issues over these cases was disconnected between scientists and public in general. In the opinion of several scientists the ethical challenges were ignored and the idea of a neutral science with no direct connection to the social environment was dominant.

The Conference for Synthetic Biology of May 2006, celebrated in Berkeley, California, called for a voluntary code of conduct to self-regulate the research in this field (Synthetic Biology, 2006). The proposal was confronted by 38 civic organizations led by the ETC Group demanding broad public debate regarding regulation and immediate governmental supervision for the creation of synthetic life. Nevertheless, there seems to be far less public dialogue regarding the impact of these technologies than it was demanded, and much less influence of civil society in the regulation and supervision of synthetic life production.

The ETC Group has also reacted to the Venter Institute's aforementioned patent application requesting both the USOPT and the WIPO to turn down the application on ground of the public order (safety and pubic morality). This reaction is symptomatic of the lack of public debate regarding the creation of synthetic forms of life and its consequences on public safety, the environment, and aspects of social, economic, ethical, and human nature.

The traditional study of ethical, legal, and societal implications of technology should encompass also *environmental* considerations. These studies aim to assess the various impacts of technology on human beings (individually and socially), their activities (economic, cultural, in the work place, health, etc.), and the envi-

6 Diamond, Commissioner of USOPT v. Chakrabarty, Supreme Court of the US, (June 16, 1980, N?79-136): Mr. Chakrabarty requested a patent in 1972 for a genetically modified bacteria able to degrade crude oil; the court found that man made living matter can be patented.

7 Dolly was the only survivor of 277 sheep cloned embryos by Ian Wilmut and his colleagues at the Institute Roslin of Edinburgh. Dolly presented developmental problems including early aging.

ronment. The nano scale different properties of nano scale materials should be accounted for in these analyses. As Owaldo Luiz Alves, professor at the Institute of Chemistry Unicamp in Brazil, expressed:

… the preoccupations of the new technologies are legitimate and should be part of the discussions, both in academia as in the private sector, government, and civil society. Nanotechnology is no different, given its innovative character that introduces new paradigms and distinctly opens up an ample range of possibilities. It is clear that the expected applications may be highly controversial, even risky … as compared to other risks, most of them have to do with the size of the elements we are working with, and as I originally said, could have their properties changed dramatically due to their size and shape (Alves, 2007).[8]

2. A framework for science, technology, and innovation in Uruguay.

Research and Development (R&D) in Uruguay is chiefly publicly funded, with a major role entrusted to the only public university in the country, Universidad de la República (UR). UR houses 70% of personnel dedicated to research, and receives roughly 75% of the national R&D expenditures (RICYT, n/d).[9]

Two other important public R&D institutions are the National Institute of Agriculture Research (INIA) and the Institute Clemente Estable for Biological Research (IIBCE).

The governmental administration inaugurated in 2005 did no see with good eyes the situation of the national system of science, technology, and innovation (STI) particularly due to the meager and lapsing funding of R&D efforts. In 2002, R&D represented only 0.3% of the Gross National Product GNP (PNUD, 2006); but the current administration, following recommendations of UNESCO, has committed to raise the figure to 1%, convoking greater participation of the private sector. It is worth noting that the fragmentation of the national system of innovation impedes the articulation of supply and demand for scientific and technological knowledge (with an exemption perhaps in the agricultural sector), particularly the knowledge produced locally. All these together are symptoms of the historical absence of a coherent public program for STI in Uruguay. This situation however may change in the future if the current administration's efforts for the institutionalization of the STI system meet a measure of success. These endeavors will be taken at three levels: 1) policy design and formulation, 2) policy implementation and evaluation, and 3) policy legitimation by means of engaging the stakeholders (Martinez and Chiancone, 2007).

8 Alves suggested also that Brazil has the infrastructure to support research in nanotechnology, but also that coupling research and public policy are key for guiding the emergence of nanotechnology.

9 This figure may be underestimated because in 2002 R&D expenditures were limited due to the economic crisis of Uruguay.

At the executive level, the Head of State has created the Ministerial Cabinet for Innovation (GMI – Gabinete Ministerial de la Innovación), tasked with the formulation of a national strategy of STI. The GMI is conformed by the ministers of Agriculture and Fishery; Industry, Energy, and Mining; Economy and Finances; Education and Culture; and the Office of Planning and Budget.

At the implementation level, the main responsibility falls onto the newly created National Agency of Research and Innovation (ANII – Agencia Nacional de Investigación e Innovación), which is to be advised by the new National Council of Innovation, Science, and Technology (CONICYT – Consejo Nacional de Innovación, Ciencia y Tecnología) that represents all government agencies involved in the innovation system. Like the old CONICYT, the new one is to provide advice in matters of STI to the Executive and Legislative Powers. In turn ANII, which is directly involved in the execution of policy, is to provide more specific advice regarding programs and instruments of STI promotion.[10] The linchpin of policy implementation will be the Strategic Plan of STI (PENCTI) to emerge from a national dialogue with all stakeholders in the innovation process. The legitimation level comprises all participants of the innovation system, that is, the producers of knowledge and innovation (scholars, institutions of innovation, industry, etc.).

A study sponsored by the Inter-American Development Bank (IDB) and conducted by researchers at the Universidad de la República concluded that the situation of the Uruguayan STI system was "deeply impoverished" (Bértola, *et al.*, 2005); characterized by low productivity, a waning culture of innovation, and disjointed networks.

The current government has signaled its intention to promote technological development with the expectation of improving the country's competitiveness and its very capacity to sustain economic growth on its own innovative potential (PDT, n/d). The following economic sectors were identified to be crucial for future investment in science and technology (GMI, 2005): agriculture networks (livestock, lactose, rice plantations, forestry, and fishing), tourism, biotechnology and pharmaceuticals (public health, sanitary and phytosanitary), alternative energy sources, information and communication technologies, and natural resources and environment.

It is evident that setting out a national strategy, a top-down approach to STI policy (O'Donnel & Oslak, 1975), may nurture tensions between the government and the civic groups that bear the weight of the policy outcomes. It is still fresh in the Uruguayan memory the social discontent educed by the National Program of Bio-security funded by the European Union under the MERCOSUR Program for the Development of Biotechnology (see Presidencia de la República Oriental del Uruguay, 2006, and Union Europea-MERCOSUR, 2005); civic groups and advocacies cried out the disregard of this program for public participation, particularly

10 Created in December 19 of 2005 by Law Nº 17.930 Article 256, of the National Budget and renamed to ANII in December 28, 2006 by Law Nº 18.084.

that of the National Committee of Bio-security (Redes Amigos de la Tierra, 2007).

The current three-level approach to STI policy may avoid this type of conflict; this policy will set strategies and priorities in a dialogue with various publics potentially affected by the development of nanotechnologies.

3. Catalysts of network formation.

The conformation of the Group of Nanotechnology Uruguay (GNanotech-Uy) illustrates the successful formation of research networks that may promote a healthy and socially sound development of nanotechnologies in Uruguay. The following events marked the development of the GNanotech-Uy and its relationship with local entrepreneurs and governmental institutions:

• Journalist Daniela Hirschfeld identified fifteen scientists researching nanotechnology in Uruguay, all working in different research units in Montevideo.[11] This survey was completed at the same time a seminar on social and economic implications of nanotechnology was offered by Guillermo Foladori (May, 26-27/2006), of the Latin-American Nanotechnology and Society Network (ReLANS). This seminar was sponsored by the Latin-American Region Secretariat of the International Union of Food, Agriculture, Hotel, Restaurant, Catering, Tobacco, and Allied Workers (IUF –ReL-UITA), the Bertolt Brech House, and the Department of Architecture of UR. A modest sample of civic groups, yet representative of the early interest of various publics to engage scientists in the discussion of nanotechnology and its impacts. An early outcome of this seminar was the incorporation of social scientists in ReLANS to collaborate in the regional effort to understand nanotechnology in society (see for further reference www.estudiosdeldesarrollo.net/relans).

• The Uruguayan Society for the Advancement of Science and Technology (SUPCYT – Sociedad Uruguaya para el Progreso de la Ciencia y la Tecnología) gathered the fifteen researchers of GNanotech-Uy for the publication of an article in SUPCYT'S journal *Uruguay with Science (Uruguay Con Ciencia)*. The article introduces the scientists, the lines of research, and further detail on their fields of work (GNanotech-Uy, 2006).

• SUPCYT, together with Fundación Zonamérica and the Uruguay Chamber of Industry, organized a seminar entitled "Nanotechnology: opportunity for large innovations" in September 2006. In this seminar, local developments and future prospects of nanotechnology were presented to entrepreneurs, researchers, and students.

• The Uruguay Chamber of Industry, through its Center for the Administration of Technology (CEGETEC – Centro de Gestión Tecnológica – CEGETEC – de

11 This was done with the purpose of covering the Science section of the newspaper Búsqueda (June, 8, 2006). Together with the article of the journalist a note on the Seminar on nanotechnology simultaneously held was included (Personal communication with Daniela Hirschfeld 03/9/07).

la Cámara de Industrias del Uruguay) seeks to strengthen the links between knowledge producers and the industry; as well as between national and international networks. Since February of 2007, CEGETEC's Program for Technological Development (PDT),[12] is supporting G-Nanotec-Uy for this group to allow its members to participate in local and regional conferences and seminars. PDT is supporting three areas: nutraceuticals, biomedical devices and nanotechnology. Examples of the regional workshops are the conference *Encuentro NanoMercosur Ciencia, Empresa y Medio Ambiente* (Buenos Aires, August 2007) or the workshop *Fortalecimiento de la Relación Universidad/Empresa con Apoyo de Cooperación Internacional* (Montevideo, July 2007).[13] CEGETEC has celebrated agreements with the Argentinean Nanotechnology Foundation and the Universidade Estadual de Campinas in Brazil, and the Universidad Autónoma de Barcelona in Spain to expand the local capacities through scientific collaborations and access to laboratory equipment and facilities. Likewise, under the auspices of CEGETEC, a series of meetings of G-Nanotec-Uy and five local companies resulted in direct collaborations with at least three of the fifteen scientists. Moreover, CEGETEC is seeking assistance form the European Union to expand the scope of collaboration with G-Nanotec-Uy and position nanotechnology as a priority in Uruguay's STI policy. In addition CEGETEC is lobbying the government to declare nanotechnology as a strategic field of research and innovation in the country.[14]

4. Synopsis of nanotechnology in Uruguay

Uruguayan nano-research is done chiefly by the scientists of G-Nanotec-Uy. This is, as mentioned above, a multidisciplinary group that combines the expertise of scientists working in different laboratories at the Universidad de la Republic (UR) and the IIBCE. The group is constituted as follows (Pereyra, 2007):

- Group Nanobiology, Department of Proteins Nucleic Acids at the Institute of Biological Research at IIBCE. Studies ion transport through biological membranes through natural nanotubes (nano-structures at the core of the cell). This group is part of the Artificial Biomembranes Project of the South-American Network of Nanobiotechnology and Biomimetic Systems.
- Group NanoMat, at the Crystallography Materials and Solid state Laboratory of the Chemistry Faculty, UR. Researchers applications of nanotechnology are to

12 PDT is dependent of the Ministry of Education and Culture, and funded by the Inter-American Development Bank.

13 The workshop was organizad by CEGETEC in Columbia Hotel in Montevideo, where talked, between others, the director of the Department of Innovation, Science and Technology for Development (DICYT), and the president of the new ANII, the Secretary of the Commission on Science and Technology of the Chamber of Industries of Uruguay, the director of the CEGETEC, and several researchers from G-Nanotech Uy and also from Spain and Argentina (Cámara de Industrias del Uruguay, 2007).

14 Interview with the director of CEGETEC (August 08, 2007).

new materials, and have developed, so far, a magnetic graphite (patented and licensed to the Brazilian Companhia Nacional de Grafite]). This group is also advancing medical applications including a vehicle that once introduced in the blood stream may be positioned in the body my means of an external magnet; which could be used for localized discharge of drugs, to contrast advanced magnetic resonance imaging, or as a bio-marker.

• Laboratory of Biomaterials, Institute of Biological Chemistry, School of Sciences, UR. This lab studies molecular interactions at the nanoscale; for instance, current research focuses on the electrochemical properties of biomolecules, such as the cytochrome C and gold nanoparticles. The lab also works the synthesis of nanoparticles such that they are absorbed into pharmaceuticals and biomolecules.

• Unit of Analytical Biochemistry, Center of Nuclear Research, School of Sciences, UR: Using fractal theory studies the exposure of cytochrome C to amino-acids to develop biosensors from ADNd's gene-sensors and immunosensors of anti-PSPB (cow fertility protein).

• Unit of Radio-Pharmaceuticals, in the Center of Nuclear Research, School of Sciences, UR.

• Laboratory of Physics of Solid State at the Institute of Physics, School of Engineering, UR. Advances research in new materials, such as nanothreads for integrated circuits from copper, silver, nickel, seleniur of cadmium are developed.

Uruguay participated in the elaboration of the Framework Program on Science and Technology of the MERCOSUR and Associated Countries (Programa Marco de Ciencia y Tecnología del MERCOSUR y Países Asociados).The first MERCOSUR summit on science and technology for associated countries (May 30, 2006) set up the Action Plan of Buenos Aires to advance scientific research and technological development, including explicitly nanotechnology (see summit declaration, 'paragraph c'). The Action Plan will constitute a web of Centers of Excellence (summit declaration, 'section 5') that include the following regional research agenda (FAN, 2007):

• Nanostructured Systems for Drug Delivery at the Nanoscale Project, in conjunction with the department of Pharmaceutical Sciences at the Universidade Federal de Santa Catarina (Brazil) and the Laboratory of Targeting of Drugs of the Universidad de Quilmes (Argentina).

• Artificial Biomembranes. Project jointly with the department of Physics at the Universidade Federal de Santa Catarina (Brazil) and the Universidad Nacional de La Plata (Argentina).

• Synthesis and Characterization of Ceramic Materials at the Nanoscale

• Magnetic Graphite. Project for the development of new carbon materials. The Project is a joint effort with Universidade Federal de Sao Carlos (Brazil).

• Regional cooperation for the development of nanomateriales with potential technological applications relevant to the region. Program for scholarly collaboration and cross border mobility in the humanities and technological development areas from the Network of Macro-universities of Latin America and the Caribbean.

The researchers at G-Nanotec-Uy recognized that Uruguay's laboratory infrastructure and specialized equipment is insufficient for an even modest expansion of the nanotechnology research portfolio. They protest the lack of government support for the education of scientists in fields compatible with nanotechnology. These last points should be taken seriously in a preparation of the national STI strategy. G-Nanotec-Uy has not extended its research program to social sciences and ELSI of nanotechnology.

5. Ethical, Legal, and Societal Impacts of Nanotechnology in Uruguay

The European Union's Group of Ethics in Science and New Technologies has recently prescribed to set aside 3% of the budget for research in nanotechnology to conduct ELSI studies (CORDIS, 2007). This report advises the European Commission to promote the debate of ethics in nanotechnology through a European network under the Framework Programme 7. It is hoped that this network would: gather ethicists in all fields involved, foster a greater understanding of ethical issues emerging from the advances in nanotechnology and nanomedicine, promote education in these fields, and articulates a code of ethics for work at the nanoscale.[15]

The absence of an open civic debate on the impacts of nanotechnology is put in evidence by the industry's labeling practices. In the forum *Encuentro Nano* MERCOSUR 2007, Lux Capital Investment and Veneto Nanotech (US and Italian firms respectively) both gave the same explanation for the absence of labeling nanoproducts as such: they did not want to risk the negative reaction experienced with GM food.[16] It is worth noting that consumers in other countries, such as Taiwan, are inclined to buy state of the art products labeled accordingly.

6. Elements for a national plan for nanotechnology

The government of Uruguay has not established an organized effort to advance nanotechnology. If Uruguay is to benefit from the current state of affairs in science, technology, and society, its government needs to produce responsible innovation

15 The European Commission's Sixth Framework Programme executed a budget on nanotechnology of ?1,360 millions and estimates a budget of ?3,500 for the Seventh Framework Programme.

16 Presentations by Peter Hebert CEO from Lux Capital Investment and Dr. Nicola Trevisan. CEO from Veneto Nanotech (Italy) in the workshop *Ciencia, Empresa y Medio Ambiente*, August, 7-9, 2007, Buenos Aires, Argentina, organized by the Fundación Argentina de Nanotecnologia.

policy. This is to say, policy that considers benefits and risks across multiple dimensions (health, economic, cultural, labor, ethical, environmental, etc.). Moreover, this national effort should incorporate nanotechnology as a strategic component.

The juridical principles of prevention and precaution, acquired renewed relevance in the dawn of nanotechnology. The State, the public administration, and the citizenry are entitled to deploy the full force of the legal and administrative system to protect their rights and liberties if they are threatened by the emerging technologies. Regulatory policy should as well privilege civil rights and public health and safety over the economic interests of firms. The Global Environment Outlook of 2007, presented in Nairobi at the beginning of 2007, make this concern explicit:

The New Opportunities and Risks of Technology Nanotechnology.

…..

The technology, which currently accounts for around 0.1 per cent of the global manufacturing economy, is set to take 14 per cent— or 2.6 trillion US dollars worth— of the market by 2014.

…..

But the report warns: It is not clear whether current regulatory frameworks are adequate to deal with the special characteristics of nanotechnology. To date no government has developed a regulatory framework specific to nanotechnology. A balanced approach is required to maximize benefits while minimizing risks (UNDP, 2007).

We advocate the use of the precautionary principle regarding the development of nanotechnology. As we understand it, the principle requires an ex-ante certainty of benefits and costs related to new technology, which is somewhat opposite to ex-post disaster management of technological accidents or unintended consequences.

Nanotechnology policy should consider ELSI not from the financial perspective, but the public interest. This perspective demands the participation of specialists of all disciplines, both natural and social sciences, as well as the participation of organizations representing users and consumers of technology.[17]

As mentioned earlier, the national STI strategy, called PENCTI (Plan Estratégico Nacional en Ciencia, Tecnología e Innovación), is under preparation, and it will become referent for action of ANII, the research and innovation agency. ANII will prepare, organize, and administer STI policy and facilitate the cooperation between public and private interests involved in the production and use of knowledge.

It is of paramount importance, now that PENCTI is prepared, to infuse it of the notions expressed in the preceding lines that amounts perhaps to a responsible STI policy. Uruguay is a small country, geographically, demographically, and economically; thereby, its opportunities to compete on a par with other countries are rat-

17 The Law of Defense of the Consumer (N?17.250) establishes, among other, the right to information regarding the product being so

her scarce. Nevertheless, precisely the small size of its scientific establishment may represent an advantage given that the emerging Strategic National Plan on Science Technology and Innovation will include from its very beginning a responsible nanotechnology policy guided by ELSI studies.

The most basic aspects to consider by any national nanotechnology plan are:

a) Prioritize research aimed to satisfy social needs. While STI policy is often motivated by the competitiveness of the national industry, this goal should be subordinated to the distribution of benefits to the broad base of society and not only privileged economic sectors.

b) The analysis of benefits and risks should encompass ethical, legal, and societal implications, as well as environmental impacts. Emphasis should be put on multidisciplinary research in the field of natural and social sciences and the humanities.

c) Regulatory policy should rely heavily on the precautionary principle. Imported products with nano-components as well as local research in nanotechnology, must provide compelling evidence that they do not pose serious risk to public health and the environment.

d) Regulatory policy should also consider the full life cycle of all products with nanocomponents from its production, through its introduction in the consumer market and use, to its disposal and that of any remaining materials or elements in the nano-scale.

e) Guarantee the right of all citizens to political participation and their right to freedom of information. This can be accomplished by: empowering all social groups and associations to participate in the process of making STI policy, by translating technical into colloquial language for the citizenry and into clear legal Spanish for the regulation of research, production, and commercialization, and by imposing full disclosure of research findings.

f) Promote the development of STI for world peace. This is not a trivial matter, considering that the larger countries invest significantly in R&D for military defense.

Concluding Remarks

Nanotechnology is a new topic of research in Uruguay and an even a newer one under the public light. This fact allowed for the only group of researchers to come together in a singular exercise of network articulation.

Because nanotechnology is developing relatively quickly, individual or interest group action will prove inadequate to deal with the broad public health and environmental impacts of nanotechnology; only national public policy can fit the bill.

The national strategy PENCTI is the optimal instrument to introduce nanotechnology in the public agenda. A central concern of public policy design is the weighing of risks and benefits that society bears at several levels (health, economic, cultural, labor, ethical, and environmental). The Uruguayan scientists dedicated to nanotechnology would be wise to invest some of their resources in studies of ethical, legal, and societal implications, as well as environmental impacts of nanotechnology. Quick progress in the social studies of science will position Uruguay at the regional vanguard of research in nanotechnology.

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Nanotechnology in the Andean Countries[1]

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1. Nanotechnology in Bolivia and Ecuador

Between 2005 and 2007, several efforts to develop nanotechnology in Latin America were consolidated and new ones undertaken (Garcia, 2005; Foladori, 2006a and 2006b). In many countries of the region nanotechnology has been recognized as a field of strategic development, as is the case of Argentina, Brazil, Costa Rica, Mexico and Chile, where a diversity of actions tending to its control are being executed.

The situation of nanotechnology in the Andean countries is completely heterogeneous. The science, technology and innovation (ST&I) policies in these countries, directed to the transformative technologies and their convergence, differ in their approach and treatment, and are being affected by the problems that are common to all public policies directed to science and technology in the Latin American region (Gupta and Aguirre, 2006).

In **Bolivia**, there is no research, education or monitoring activity in nanotechnology and its ST&I policy, contained in the National Development Plan, contemplates in a direct way the development of Information and Communication

1 This paper presents some of the more important results of the Project "Convergent Technologies in the Andean Countries: what is being done and what should be done about them?". The Project was executed between April 2005 and September 2007, under a grant from the International Development Research Center of Canada and the support of the Rockefeller Foundation. The Project was coordinated by the Institute of Social and Economic Studies of the Catholic University of Bolivia and was conducted by experts and assistants in the five Andean countries. The full version of the Final Research Report and other Project outputs can be found in the Project`s webpage (www.iisec.ucb.edu.bo/tecnologia).
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Technologies (ICT) and only in an indirect way the development of biotechnology (Aguirre et al, 2006). The policy in Bolivia strives to define and to implement a "Bolivian Innovation System," constructed from the traditional science institutions and from the traditional knowledge existing in the indigenous and peasant communities.

In **Ecuador**, in 2005, the National Science, Technology and Innovation Policy 2005-2010 was launched and established as its main objective: "to strengthen the scientific and technological capacity of the country, through the impulse of basic and applied research, that corresponds to high-priority needs of the population, to improve its quality of life, and to promote innovation and technology transfer to increase the productivity and competitiveness of the nation".

The policy calls for the strengthening of the capacity of the National System of Science, Technology and Innovation (NSSTI). The Plan, derived from the policy, identifies a set of strategies to reach the main objective, and indicates among others, that the financing will go to research projects in different areas, between them basic sciences and material sciences, that include nanotechnology. Also the Plan calls for the development of biotechnology and the massive diffusion of ICT's as well as the diffusion of science.

In the area of nanotechnology there are recent initiatives for its development, and some researchers have started with the characterization of nanomateriales by chemical means as well as to propose the application of nanotechnology to the food sector. Approximately 15 active researchers are working in nanotechnology or related areas in Ecuador.[10]

2. Nanotechnology in Colombia[11]

In Colombia, research in nanotechnology was initiated in 1973, by specific groups in the basic sciences. Today, there are 34 groups that conduct research projects in nanotechnology and convergent technologies. Fifty-six per cent of these research groups are catalogued as Type-A by COLCIENCIAS.[12] The participation in basic research in nanotechnology by the non-categorized groups is minimal. Only three have not been classified, and two have only been registered.

In spite of the relatively high number of research groups that develop nanotechnology projects, the number of groups dedicated exclusively to this field is very small (2 of 34), one of those is involved in carbon fullerenes and nanotubes, and the second in deposition of ultra-thin films, while the rest of the groups work on convergent technologies.

10 A list of researchers in four Andean countries can be found in the Final Research Report of the Project.

11 Forero and Gómez, 2007

12 The centers of Type-A are those that are recognized as scientific publication producers, with a minimum number of researchers with doctoral degrees and other attributes of centres of excellence.

The A category groups have a high average of researchers with doctoral studies (8.89), superior to those in B category groups (2.29). In the same way, the A group shows a greater amount of doctoral, master and degree students than the other groups. It can thus be deduced that the higher productivity of the A groups is related to the greater number of doctors and students in their research projects.

The majority of the research projects in nanotechnology that are developed in Colombia have been focused in the physics of materials, or in basic studies in chemistry and applied engineering. The scientific publications related to nanotechnology present a growth tendency in the last 10 years, but with significant changes, the increasing scientific productivity that is observed between 1999 and 2000 is due to the effect of the research results produced by the establishment of the National Nanotechnology Initiative (USA), in which Colombian groups participated, and by the resources destined to research derived exclusively for nanotechnology through competitions.

Several academic events related to nanotechnology (194) have taken place in recent years. Many of them had as an objective the diffusion and popularization of nanotechnology as an emerging research area. The more outstanding academic events in the last three years were:

• Micro and Nanotechnology Congress, Los Andes University (30/3, 2004).
• Nanoforum 2005 (25-26/8): Organized by the National Council of Science and Technology, IEEE Section. Colombia.
• Cycle of Conferences of Dr. Carlos Cabrera, Director of the "Center for Nanoscale Materials" of the University of Puerto Rico, Rio Piedras campus in the Pontifical University Javeriana (Bogotá, 2006).
•National Symposium of Nanotechnology: The Revolution of the XXI Century (15-16/ 2006). National University of Colombia, Bogotá, organized by the Latin American Foundation for the Promotion of Science FUNLACI and the participation of researchers and professors of the National University, BUNAIMA, IEEE-Colombia, CORPOGEN, the Center of Excellence in New Materials-CENM, the University of the Valley, the Javeriana University, the Colombian Association for the Support of Research, and other nongovernmental institutions at the Latin American level.

At the moment, in universities of Colombia, numerous formal courses and continuing education courses are provided that treat nanotechnology as a module.

The non-specialized diffusion of nanotechnology and convergent technologies shows a low volume of articles related to nanotechnologies. Only 78 articles have been produced in the last three years, with national newspapers' appearances having contributed the most to this number.

The larger number of diffusion of articles explain what nanotechnology consists of, or generalizes about possible developments in nanotechnology. Another frequent subject in the diffusion of articles is related to nanostructured materials, which goes along with the thematic concentrations of the existing research groups.

A high percentage of the articles' sources are the research groups and national projects, which explains the concentration in the same thematic areas. It is interesting to point out that, in spite of more than 15,000 articles on nanotechnology that are annually produced in the world, a greater use of national sources (73 per cent) than international sources (23 per cent), is made by the local newspapers and other journals.

Even though the better documented articles stand around 88 per cent, the weaker or badly informed articles are in the sources of greater diffusion and therefore can generate a greater negative effect in the perception and understanding of nanotechnology and convergent technologies. In many cases, the quality of the the articles is poor and the level of detail is low. Mistaken conceptions about nanotechnology are common, probably as a result of the insufficient research of those in charge, which affects the social perception of these technologies.

To improve this situation, a group of Colombian researchers have published a book directed to a non-specialized audience, to broaden the understanding of nanotechnology concepts and practices (Giraldo, G.J. et al, 2007)

The social perception of Nanotechnology

With the purpose of measuring the knowledge that the public has in Colombia about nanotechnology, a survey was made of 92 people (81 pre-degree students and 11 university professors) that attended the "National Symposium of Nanotechnology: The Revolution of the XXI Century". These people were chosen because they showed at least a basic knowledge about nanoscience and nanotechnology.

The group identified nanotechnology projects in academic courses, for example the one led by the Pontifical Javeriana University in Bogotá about applications to cancer. Among the people that completed the survey, there was a general perception of the competitive advantage of Colombia has, based on its biodiversity, which explains why medicine and bio-nanotechnology are perceived as the areas with greater competitive advantage. This result contrasts with the real participation of the research groups in projects related to nanotechnology.

In general, it is perceived that the generation and application of nanotechnology in Colombia can generate a positive impact on economic growth (91 per cent). The negative perceptions (8 per cent) on the economic impact are of those that have doubts about the global competitive capacity of the country. It was remarkable to find such a pessimistic outlook among those persons interviewed about the possibilities to develop a competitive industry based on nanotechnology in Colombia, nevertheless, most of those interviewed see nanotechnology as a generator of opportunities to enterprise growth (98 per cent).

The survey undertaken in Colombia shows that a high percentage of the interviewees are aware of the potential risks related to the application and research of nanotechnology, 46 per cent believe that research in nanotechnology presents risks, and 67 per cent believe that the application of nanotechnology presents risks. The risks that are perceived are related to the use of nanotechnology for war-like aims (14 per cent) and to the general toxicity of nanoparticles (13 per cent). However, in the survey, the miscellaneous category predominates (39 per cent), indicating a varied perception on the nature of these risks.

Although in global studies, the control of inherent risks to convergent technologies has not yet been fixed, the interviewees present a high degree of optimism about what can be done through traditional organizations dedicated to control (71 per cent) against 9 per cent who think that there is no possible control. It is interesting to confront the effectiveness and desire of legal regulations against the application of voluntary codes of ethics. More than two-thirds of thosee interviewed consider that a code of ethics decided by the researchers is sufficient. The confidence in the capacity of self-regulation of the scientific community and users of biotechnology is generalized. There is a great diversity of recommendations for the creation of regulatory environments to mitigate the possible risks of research and the use of nanotechnology.

Public policies

There is no clear vision among those interviewed about how some laws can stimulate or inhibit the development of nanotechnology. The responses obtained to this question point to generalities. The answers related to problems that are faced in Colombia to develop research projects or applications in nanotechnology vary widely.

Colombia has, like other more traditional countries in science and technology in the region, significant experience in the definition of STI policies and plans. In 2004, COLCIENCIAS selected 8 strategic areas for the development of competitiveness and productivity of the Colombian economy; one of these strategies is "Advanced Materials and Nanotechnology". In February of 2007, the National Department of Planning (DNP, 2007) proposed the "Vision of the Second Century" destined to lay the foundations of economic growth and social development based on science, technology and innovation. The proposal has two leading principles that should be applied to reach a new society by 2019:

- To consolidate a deeply democratic political model, based on the principles of freedom, tolerance and brotherhood.
- To strengthen a socioeconomic model without exclusions based on the equality of opportunities and with a State that guarantees social equity.

These two principles are developed, at the same time, into four main objectives:

- An economy that guarantees a greater welfare level.
- A more egalitarian and solidarity-oriented society.

•A society of free and responsible citizens.
•An efficient State in the service of citizens.

Toward the fulfillment of these objectives, strategies have been proposed that identify both specific goals as well as actions to obtain them. For each goal, base lines were identified, within sectoral conditions. Within goal 1 “To Increase the Generation of Knowledge,” various lines of action have been established, among them:

• Support scientific, technological and innovating research in the area of energy and materials, biological processes, agro-food and biodiversity.
• Support to the scientific, technological and innovating research in the area of human studies and environment.
• Support to the scientific, technological, and innovating research in the management of knowledge, social applications and technology convergence.

From the institutional perspective, in 2005, the National Board of Nanoscience and Nanotechnology was established as a non-profit organization, within the IEEE of Colombia and attached to the IEEE Nanotechnology Council, and whose mission is “to promote and to generate training, diffusion, research and technology development tasks in nanoscience and nanotechnology, as well as to open spaces of joint participation between the academy, industry and the State in the local and regional levels to make viable the appropriation, generation and application of knowledge in this strategic line for the XXI Century”.

The Board is at present committed in different areas of interest that include: self-assembly, nanoscale replication and control; treatment of cancer; nanoelectronics and molecular electronics; nanophotonics; nanomaterials; computational nanotechnoscience; quantum and molecular computation; nanorobotics; bionanotechnoscience and ethical and social implications of nanotechnoscience.

More recently Nanocolombia has been created as a private institution whose mission is to promote investments in companies or joint ventures of nanotechnology.

3. Nanotechnology in Peru[13]

In Peru, the activities that are linked with nanotechnology research and dissemination are still nascent, even though they have increased considerably in spite of not being built-in within a specific initiative of government, like in other countries.

The first nanotechnology research began in the most important universities in the decade of the 90’s, as a part of the study of phenomena in the area of materi-

13 Vega-Centeno, Morales y Roselli, 2007; Gutarra 2007b.

als science. In those years, active groups in the manufacture and characterization of thin films existed, that eventually worked with coatings of thicknesses smaller than 100 nm for optics and optoelectronic applications. Later, a sustained increase in nanoscale work took place, impelled by two important factors: a more frequent collaboration between groups of physicists and chemists, that complemented the synthesis of nanostructures with their characterization and applications, and secondly, the acquisition of electronic microscopes, that allowed the observation and characterization of materials.

Today, the universities have greatly increased their research activities in this subject, adjusting budgets and adapting equipment from their traditional lines of research. The four main Universities in the country, National University of Engineering (UNI), National University Mayor de San Marcos (UNMSM), Pontifical Catholic University (PUCP), and the University Cayetano Heredia (UPCH), have small groups working on nanotechnology and even though they share some specific projects, an integrating plan that unifies human resources and the available infrastructure has yet to be established. In the Universities located outside of the capital city, the activity is more limited Of particular note is the research being carried out at the National University of Trujillo and the Saint Agustín University in Arequipa.

The number of active researchers in this field is still small (17 active researchers have been identified) and the number of publications is also very limited, however, it is foreseeable that new financing by the Interamerican Development Bank and the signs of institutional support will produce an increase in these indicators for the next years. From the organizational point of view, an Advisory Committee on Nanotechnology has recently been created.

Research projects, education and training

In general terms, a greater dedication to the characterization and applications of nanomaterials on behalf of the groups of solid state physics and materials engineers can be identified; chemists and chemical engineers have become more involved in nanocompound synthesis, using techniques like sol-gel, coprecipitation, etc.; biologists and doctors have shown special interest in the development of biosensors and techniques for drug delivery.

Among the applications of present nanotechnology development is the decontamination of water, which constitutes an important issue mainly in the Andean zones with a high presence of mining activity. Along this line, UNI, UNMSM and PUCP have tackled the problem with different techniques, one of them using photocatalytic nanoparticles of titanium dioxide and zinc oxide exposed to artificial UV or solar radiation. These systems have been proven in the field with encouraging results but require improvement. Another technique being tried is based on the use of modified clays as absorbents, as well as in porous compact filters. This option has several advantages, as clay is a low-cost and abundant mineral, has very good efficiency as an absorbent and the manufacturing technique of the filters can be quickly transferred to local societies because work in ceramics is ancestral in several Andean populations.

Groups of the four universities have been united in a project to develop ISFET biosensors for the diagnosis of micro-pathogenic organisms or toxic biomolecules based on the detection of the link antigen-antibody. In this line there is a very important participation of the UPCH, a university recognized as a quality institution in research in biology and medicine and with particular interest in innovative techniques of diagnosis of diseases such as tuberculosis, cholera, hepatitis etc. At UNI an alternative to immunological biosensors is being developed, based on the use of nanoporous photo-luminescent silicon for the detection of bacteria that operate by visual inspection of the different colorations that this material adopts when some species adhere to its surface.

In the area of synthesis of nanostructures, the consolidation of research groups is found, especially of chemists, with the capacity to obtain nanoparticles of gold with coverings of amorphous silicon (UNMSM) and of magnetic nanoparticles of iron oxide (UNI).

A basic aspect that nanotechnology deals with is being developed by PUCP. The Group of Quantum Optics is working around “quantum computation,” to be able to produce a first prototype of a quantum computer based on “ionic traps.” It is in this area where this Group has made contributions referred to as “photon - phonon translators.” Additionally, work around the “cloning of quantum machines” is being executed, which is closely related to quantum computers.

To surpass some of the difficulties for the characterization and the prediction of properties of nanostructures, expert groups in computational methods are being trained at the UPCH, UNMSM and UNI, each one of these have computer systems that are being interconnected.

On the issues of education and training, attention to young researchers is of primary importance. The convenience of incorporating courses of biology in the first courses of the graduate careers like sciences and engineering has been discussed (and in some cases put in practice at a pilot level, UNI). This modification would increase the capacity to solve interdisciplinary problems that are characteristic of nanoscience and nanotechnology. In the same way, the need has been identified to increase and in some cases to incorporate courses of quantum physics in the engineering programs, especially in chemical engineering.

Representatives of UNI and UNMSM have considered the convenience of elaborating common courses for postgraduate studies. At the moment, only UNI has incorporated a formal course on nanomaterials in their master courses in physics and chemistry programs.

Table 3.1 provides a short list of some academic and diffusion events that show an increasing interest in nanotechnology.

Table 3.1: Recent academic and diffusion events in Peru

Event	Organizer	Topic	Date
Nanotechnology Seminar	National Academy of Science and Technology	Fundamentals of nanoscience and advances in local research. For post-graduate students	March 2005
Diffusion in a national newspaper	La Repûblica	Nanotechnology and health	October 2006
IV Peruvian Congress of Material Sciences and Technology	Peruvian Materials Society	Course: Nanomaterials for electronics, photonics and life sciences. Magnus Wallender, Chalmers University, Sweden. Course: Nanoparticles, physical methods for preparation and characterization. Frederic Chandezon. CEA, Grenoble.	November 2006
Nanotechnology Forum	National Academy of Science and Technology	Development and perspectives of biosensors and nanomaterials. Local researchers	January 2007
XXIII Peruvian Chemical Congress	Peruvian Chemical Society	Course: Nanoparticles: Preparation methods and characterization techniques.	March 2007
Participation in the Workshop Nano-MERCOSUR (Buenos Aires - Argentina)	Argentina Nanotechnology Foundation	Panorama and perspectives of micro and nanotechnology in Peru	August 2007
National Project Competition (PROCYT)	National Council for Science, Technology and Innovation	Nanotechnology is considered as a subject of financing	July – September 2007

Policies and perspectives of development

Nanotechnology constitutes one of the thematic axes of the National Materials Program that forms part of the National Project of Science and Technology 2006 – 2021 (NPST). The projects on nanotechnology proposed in the Program have been elaborated by the academic and enterprise sectors with technical feasibility criteria and social priority. On the other hand, the National Academy of Sciences has also promoted discussion meetings between researchers, mainly in the specialties of physics, chemistry, biology and engineering, in order to unify the research efforts and to form multidisciplinary and inter-institutional networks.

In November 2005, the National Strategic Plan of Science, Technology and Innovation for the Competitiveness and Human Development (PNCTI) 2006-2021 was adopted. It identifies knowledge areas necessary to develop in order to meet the demands of priority sectors, among them transformative technologies, and it defines a set of national, regional and special programs. The programs for the development of transformative technologies are classified as “National Transversal Programs.”

As part of the Plan, the manipulation and design of nanomaterials are some of the main issues in the Materials Program (PROMAT) (Gutarra, 2007). The aim of the latter is to control, manipulate and design nanoscalar materials with potential use in environmental control, agriculture, medicine, energy and construction, the development of metallic, ceramic, magnetic, semiconductor or superconductor materials; monolayer molecular growth; nanocapsules and nanoporters; design and construction of low dimension transducers and computational methods for nanostructural design.

In the Peruvian case, an appreciable coherence between the main lines of research and social demands like water treatment, health and environmental contamination can be found. This situation facilitates the possibility of unifying efforts and optimizing strategies from the technical point of view and from the possibility of managing internal resources and international cooperation resources. This may lead, in the short term, to academic sectors becoming more integrated. Nevertheless, a greater effort is needed to involve the productive sectors. Among the private entrepreneurs an interest to inquire information to see if the adoption of nanotechnology could be profitable has been observed, but they are unlikely to decide (at least at this stage) to risk capital for research. At this point, the intermediation of the state is necessary to provide incentives.

It is important to point out the considerable connection existing between Peruvian researchers who are leading groups in foreign universities, and their Peruvian counterparts. This relation has been materialized not only in the transmission of updated knowledge but often in the co-direction of projects. If this relationship is institutionalized, research in nanotechnology could be multiplied and improved in quality.

There is a limited perception, in the non-specialized public, about the advantages and risks of nanotechnology. On the other hand, the demand of information is greater than the capacity of response. Frequently the press turns to the universities for information, but due to the limited number of dedicated researchers who can provide answers, the opportunity to reach the broader public is lost.

4. Nanotechnology in Venezuela[14]

With the purpose of identifying nanotechnology researchers in Venezuela, and to learn of the results of their research, the registry of enrolled researchers by the end of 2005 in the Research Promotion Program was consulted. Also, a search through the Web of Science was made in the data base of the Science Citation Index, with the intention of identifying the published Venezuelan scientific production in indexed journals magazines to this data base (between 1987 and 15/03/2007), limiting the search to those authors belonging to any Venezuelan institution.

The search criteria in both cases was the presence of the prefix "nano" in pertinent fields ("line of research" in the Promotion Program and the fields of "title", "key words" and "abstract" in the SCI), even though this might not necessarily be the ideal indicative for an optimal search, as some authors wonder if the increasing peak of this prefix in specialized literature constitutes the appropriate terminology of an emerging new scientific field or if it is the expression of a temporal fashion.

In Venezuela, the nanoscale research activity begins to be evident since 1990 with the first scientific publications. Progressively this activity has shown a slow but steady growth, fundamentally in the last decade, with a total of 164 articles until today.

14 Vessuri and Sánchez, 2007, Goncalves, 2006

It has been possible to identify a total of 162 people who carry out nanoscale research in Venezuela. From this group, 60 declare specifically their adherence to this area of knowledge. The most productive authors are concentrated basically in three institutions: the Venezuelan Institute of Scientific Research (IVIC), Los Andes University (ULA), Simon Bolivar University (USB), and in a smaller proportion the Central University of Venezuela (UCV).

Research projects exist, but programs to articulate such activity is not found beyond the connections of individual researchers with networks or programs in other countries. The development of research in this area of knowledge has been done in collaboration with international groups and institutions. In contrast, the collaboration between the different national institutional groups is practically nonexistent.

Education and training

Recently some initiatives have risen in order to promote the study of nanotechnology in universities through the Nanoscience and Nanotechnology Schools organized by the Science Faculty of Los Andes University. The first school was crafted in the framework of the VII Venezuelan Chemistry Congress and the XVII National Meeting of Catalysis, at the end of 2005. The second event, “Latin American School of Nanoscience,” was conducted in July 2006, and was seen as a strategy to motivate graduate and postgraduate students of the Physics Department of the former university, in order to train them in this field, to create Venezuelan capacities in nanoscience.

On the other hand, as part of the Postgraduate Cooperation Program developed during 2004 between Venezuela and France, 17 programs were financed in the areas of nonlinear optics, nanoparticles used as catalysts, coatings, natural bioactive substances, asphaltens, management and control of water, emulsion formulation, process optimization and integration, oil fluids, pumping and transportation, starch and cereal extrusion, biofuel applications, animal vaccines, porous means, multiphase and cosmetic formulations.

Between the 7th and 11th of May of 2006, an International Nanoscience Conference took place in Choroní (Maracay) (ICON 2006), involving the participation of a large number of researchers and students from different academic institutions in the country. The North American participants in the event were the National Institute of Standards and Technology and NIST (National Nanotechnology Initiative) and the Center for Theoretical and Computational Nanosciences (NCTCN); from Spain, the participants were from the Autonomous University of Madrid and Phantoms Foundation; and from Venezuela, the Venezuelan Institute of Scientific Research and the Central University of Venezuela (Faculty of Sciences).

In February 2006, the VI World Social Forum Encounter took place in Venezuela. During its proceedings, there were two nanotechnology-related workshops: “Nanotechnology and environment for a possible new world” and “Nanotechnology". Both workshops were organized by ETC (Action Group on Erosion, Technology and Concentration).

Bonds between actors

Government cooperation with industry is usually an important issue for many countries for the transference of innovations in nanotechnology to industrial development. It has not been possible to identify if the active Venezuelan researchers have some relation with any foreign industries, in response to an explicit absence of demand from industries within the country. In the same way, it has not been possible to identify if the productive sector is informed (or conscious) about convergent technologies. From patent information it is possible to infer as an hypothesis that there is not much industrial activity, only three out of 41 patent requests introduced in the Independent System of Intellectual Property (SAPI) between 1986 and 2003 were produced by Venezuelan institutions (one of them from the Zulia University's Technological Park and the other two from INTEVEP, a PDVSA (the national petroleum holding) subsidiary company oriented to the generation of technological solutions for different industrial activities).

Most of the patent requests introduced in SAPI come from transnational companies, primarily from North America and in smaller numbers from France, England and Germany. The applications of these patents are particularly oriented to the development of new materials, as well as to applications in the petroleum area and pharmaceuticals.

Risks

In general terms, the Venezuelan scientific community does not conceive risks as an inherent dimension of its research activity and, when a risk is found, it is identified as an ethical problem that must be assumed by the corresponding organization. The precautionary principle, and hence risk, is a dimension that is not taken into account by the scientific community in all the knowledge areas.

Bioethics was assumed as a governing principle for ST policy when it was incorporated into the Organic Science, Technology and Innovation Law (2002) that created multidisciplinary commissions for ethics, bioethics and biodiversity in charge of elaborating the corresponding policy instruments. Today, there exist a few institutionalized bioethics committees and those that do exist do not have standardized norms that regulate their operation. The regulations approved by the Ministry of Science and Technology in 1999 establishes rules on issues of research with life organisms and environment, applicable to health, social, human and biological sciences.

The term biosecurity, introduced in this code, does not refer only to its traditional meaning (the norms that are applied to the laboratory work in the ID centers), but also to a more modern interpretation. The latter is applied to research and development projects that use biotechnology techniques, particularly those employed to obtain genetically modified organisms (GMO). The norms applied in this case try to guide the behavior of researchers and establish the necessary procedures to guarantee the correct use of GMO, the dangerous biological agents and exotic organisms, in and outside the laboratory.

The normative and control function of the bioethics committees are not free of conflict, as many researchers think that the main function of these committees is "to obstruct the development of their research projects."

The opinion of the Venezuelan scientific community on Convergent Technologies
In Venezuela, the research team prepared a questionnaire and interviewed researchers to gather their opinions about what is being done and what should be done in relation to convergent technologies, and particularly about nanotechnology. Some of the more important results and criteria gathered from these interviews are reflected in the following sections.

Situation and perspectives:
There are currently several development fields, among them: carbon nanotubes; nano-info convergence for data inscription; microelectronics; catalysts in the oil industry; magnetically structured materials; magnetic nano-particles; magnetic and ferro-electrical materials; organized system structures with surfactants and polymers (liquid crystals, liposomes, nano-emulsions).

Some researchers think that nanotechnology is a "fashion" that many follow and any research result is mainly of use in foreign countries.

The existing advances, constituting isolated efforts, indicate the presence of an important potential that is not fully employed in the absence of policy. At the same time, efforts become difficult due to the absence of an industrial base that uses those advances, or finances and generates them.

The country depends upon foreign collaboration, since it does not have the basic instruments for nano-manipulation and nano-visualization. This is the reason why researchers follow lines imposed by foreign collaborators. At the same time, it is considered that international cooperation is fundamental for the development of this area because the advances made in the last 10 years can be intensified. It is considered necessary to give more support and resources to the small national groups so that they can have a better capacity for negotiation with their foreign collaborators.

The Ministry should create a National Nanotechnology Program to identify capacities, develop long-term visions, establish priorities, including a vision of the markets, and to built the necessary infrastructure, including the creation of a center specifically dedicated to nanotechnology.

Political circles should be aware that this is a technology area that requires a relatively high experience and it cannot be constructed in an instant, and that it is also expensive to achieve any expected impact or outcome.

In order to define public policies on this matter, decision makers must have a direct relation with the people involved, particularly those who coordinate the organizations involved (university directors and research group directors). An issue that must be treated within the policy is the ethical dimension.

The institutions of pre-university education must assume a special responsibility in the education of human resources, for example, introducing nanotechnology courses into the physics curricular program. These efforts should be also oriented toward human resources formation, creation of networks and the formation of research groups.

Impacts and Risks (social, economic, environmental, cultural)
Nanotechnology offers many opportunities, due to its great range of applications. Examples include the use of nanoparticles for the treatment of contaminated water, skin cancer treatment; carbon nanotubes to treat certain degenerative diseases as Parkinson's and Alzheimer's. In the case of Venezuela, the main impact would be in the economy and, at the same time, would have repercussions in for society, with the development of catalysts for the petrochemical and petroleum industry (hydrogen generation and storage) and for alternative energies (fuel cells, energy storage, photochemistry, etc.).

A general opinion exists that nanotechnology development should serve to avoid the increasing technological gap between the developed economies and the emergent ones.

It is also recognized that there may be environmental and health risks, but these are as yet unknown. It is also assumed, as in all new applications, that risk exists and the problem is one of regulation.

Diffusion to stakeholders and citizens
*T*here is awareness of the need to spread nanotechnology knowledge in simple terms to stakeholders and citizens, in order to increase general knowledge and have a greater possibility of an active participation in the development of a new society. This task is not only one for the scientific community, as the communication media have an important role.

The scientists' responsibility is to put the information at the disposal of anyone, classify it and to order it. This requires an additional effort, distinct from research. It is a task involving broad publication and participation in debates, seminars and other important venues.

Opinion of policy makers
The opinion of policy makers in Venezuela is that there is hardly any knowledge on NBIC convergence, and that in this context it is not easy to advance in policy making. Deficiencies still exist even in the most traditional technologies, for example, in chemical processing technology.

Regarding diffusion, it is viewed as highly important that the government facilitates and guarantees information to the public, taking into account their existing knowledge and education levels. A highly educated population has greater possibility of understanding the implications of these advances and supporting the policy decisions that are adopted.

Plans and policies

In Venezuela, the Second National Plan of Science and Technology (1986-1988) identified the need to develop capacities in the areas of genetics, biotechnology and information technology. Between 1988-1993, the government negotiated the first financial Program of New Technologies BID-CONICIT, which was created to finance research in five areas with potential for technology transfer to the productive sector: biotechnology, fine chemistry, information technology, electronics, telecommunications and new materials. In 1992, as part of the policy and through this Program, scholarship / loans were provided for the training of scientists in predefined areas. According to the Information System of the Scholarship Bulletin of CONICIT from 1992 to 1996, some 264 people benefited from the Program.

The New Technologies Program concluded approximately in 1999 and left not only an important number of high-level professionals for research, but also better-equipped laboratories, research projects and the Academic Network of Research Centers and National Universities, Reacciun (CONICIT, 1998). Currently, the National Fund of Science, Technology and Innovation (previously CONICIT) is conducting the Second Program of Science and Technology (BID-FONACIT II), whose main goal is the strengthening of the National Science, Technology and Innovation System.

In 2005, the National Plan of Science, Technology and Innovation 2005-2030 (PNCTI) was presented, indicating different research lines to follow in order to search for a less fragmented National Science, Technological and Innovation System and which should be more participative, integral and more in line with the country's needs, promoting endogenous development by taking advantage of the capacities and local resources, and including knowledge dialogues for that purpose. The Plan continues to identify biotechnology and ICTs as high priority areas. In this context, the Ministry is undertaking a forecast exercise that will permit the integration of nanotechnology as a substantive part of the Plan, which should be concluded by the end of 2007.

5. Communication and Dissemination of Convergent and Transformative Technologies

In the Andean countries, the context of scientific communication is heterogeneous; it follows regional tendencies, where a relatively small group of countries dominate scientific publications. In the national context, in spite of financial and another limitations, efforts for communicating specialized knowledge exist by traditional means, for example, through respected scientific journals such as the "Acta Cientifica Venezolana," Interciencia (a regional journal published in Venezuela), the Journal of Innovation (Colombia) and others.

In the case of small countries, communication and publication fails in all categories, in spite of the existing talent and the valuable results of the research that is performed. In these countries few refereed and quality magazines exists. Exceptions include the Latin American Journal of Economy, produced by the Bolivian Catholic University, and the Bolivian Journal of Physics, produced by the Bolivian Physics Society.

To better determine the level of understanding, information, communication and dissemination of transforming technologies and convergence, a survey, consultations and interviews were undertaken in Bolivia, Ecuador and Peru. These were applied to researchers at the masters and doctorate levels, directors of research institutes, as well as industrialists. In the case of Bolivia, the number of people who responded to the survey was 154, in Ecuador 25, and in Peru 50.

Table 5.1 shows the preferred media of communication of research results by the scientific communities of Bolivia, Ecuador and Peru.

Table 5.1: Preferred means of communication of research results

	Bolivia	Ecuador	Perú *
Periodic publications in national journals	14%	11%	32%
Periodic publications in international journals	7%	7%	35%
Occasional publications in national journals	9%	9%	4%
Occasional publications in international journals	6%	10%	7%
Articles published in newspapers	7%	11%	
Articles published in an Internet site	11%	11%	
Occasional interviews in TV or radio	8%	16%	
Periodic interviews in TV or radio	3%	5%	
Periodic presentations in seminars and equivalent events	23%	16%	
Other means or no diffusion	12%	5%	22%
Total	100%	100%	100%

* In the case of Peru, the category "others" include those means that are more disaggregated for the other two countries.

In the case of Colombia and Venezuela, the situation is similar to that of Peru. For the two smaller countries, the above indicators show that oral means continue to be the most common form of presenting research results. This is a very rooted cultural characteristic.

The dissemination of sciences

The science, technology and innovation policies in the five Andean countries contain an explicit declaration as to the need to popularize science and technology. Diverse efforts are being undertaken in application of this objective: seminars, training of journalists, scientific fairs, establishment of "the week of research," improvements of museums and others. Around these activities, hundreds of students and teachers have been mobilized.

An examination of the scientific community behavior around dissemination shows, in the Bolivian case, that of 154 people who works in research, 56 per cent do not make any effort to spread them to a non-specialized public. In the opinion of the same group of people, there are three main reasons that explain this situation: first, the lack of institutional incentives; second, the lack of economic resources; and third, the lack of knowledge of the channels available for dissemination (see Table 5.2). Table 5.3 shows the means employed by those who do circulate their work to the non-specialized public.

The study indicates that both communication and dissemination of science in the Andean countries must substantially be enhanced, if it is desired that science receives the support of society to move ahead, and particularly, that the transformative technologies and their convergence receive the attention that they require for future involvement from policy makers as well as of stakeholders and citizens.

Table 5.2: Difficulties found in the communication and dissemination of research results

Difficulties	Bolivia %	Ecuador %
Lack of knowledge of means for dissemination	16	13
Ex-ante restrictions of means for dissemination	8	10
Technical language of the topic	8	4
The required language	4	7
Lack of guidance and advise	6	13
Lack of methodology	5	2
Lack of financial resources	21	25
Lack of institutional incentives	25	20
Lack of security in publication	7	6
Total	100	100

Table 5.3: Means of communication of research results

Means of communication	No	%
Internet	74	46.8
Newspapers	23	14.6
Radio	10	6.3
Television	9	5.7
Journals	85	53.8
Others	53	33.5

Perception and knowledge of transformative and convergent technologies by the agents of development

Different studies in developed countries have been performed trying to determine the degree of perception and knowledge of transformative technologies and their convergence by society at large. Many of these studies have concentrated in nanotechnology (Cobb and Macoubrie, 2004; Macoubrie, 2005). They show that between 80 to 85 per cent of the public in the United States have heard little or nothing of nanotechnology; this is consistent with surveys undertaken in Europe and Canada.

For the survey conducted in the Andean countries, the results are shown in Table 5.4. As in this case, the survey was made in the academic sector and the high-institutional context. A direct comparison with the more global surveys, mentioned previously, in developed countries, is not possible.

Table 5.4: Degree of knowledge of transforming technologies and convergence in Bolivia, Ecuador and Peru

Country	Bolivia				Ecuador				Peru			
Field	Nothing %	Little %	Good %	Ver y good	Nothing %	Little %	Good %	Ver y good	Nothing %	Little %	Good %	Very good
Nanoscience	41	27	27	4	37	27	27	5	58	16	16	11
Nano-technology	34	32	29	4	24	37	33	5	63	11	16	11
Biotechnology	23	25	39	13	33	24	19	24	26	11	32	32
Biomedicine (1)	38	27	27	8	47	28	5	19	63	11	5	21
ITCs	13	16	35	35	14	19	19	47	79	11	5	5
Informatics (2)	15	20	42	23	19	14	33	33	79	11	5	5
Cognitive (3)	40	30	25	5	37	19	33	9	79	11	11	-

(1) Including genetic engineering
(2) Including advanced computing
(3) Including cognitive neurosciences

It was not expected that the people who answered the survey, in spite of their academic credentials, would have a sufficient knowledge of the technologies, but it was surprising to find an extremely modest result. The informed academics signaled the need of creating debates and dialogues around what is called in this paper "the convergence challenge."

It is interesting to examine the sources of information that people have of these technologies. Table 5.5 shows the case of Bolivia and Ecuador. Without doubt, the internet is the main source of information in technological advances and local publications are relatively under-represented compared with others.

Table 5.5 Sources of information on transforming and convergent technologies

SOURCE	Bolivia (%)	Ecuador (%)
Internet	19	18
Scientific publications produced by nationals	7	7
Scientific publications produced abroad	15	17
Articles published in newspapers	9	7
Participation in seminars and equivalent events of the scientific community	8	7
Participation in seminars and equivalent events of the international scientific community	8	11
Short term courses	9	11
Long term courses	6	6
Formal higher education programs (with academic accreditation)	12	8
By virtue of membership in academic associations and organizations	6	7
Others	1	1
Total	100%	100%

Also, respondents were surveyed with respect to the degree and intensity of the existing coverage in the different mass media about science and technology.

Table 5.6 shows the result of these opinions for the Bolivian case.

Table 5.6: Opinion on the degree of coverage of media on scientific and technological information (Bolivia)

	Internet	Newspapers	Radio	Television	Journals	Others
Sufficient	81.6%	8.9%	0.6%	19%	63.9%	3.8%
Insufficient	9.5%	72.1%	70.9%	61.4%	22.2%	3.2%
DK/NR	8.9%	19%	28.5%	19.6%	13.9%	93%
Totals	100%	100%	100%	100%	100%	100%

Conclusions

• With the exception of Bolivia (and Venezuela, which is in process), all policies and plans of ST&I in the Andean countries indicate explicitly the need to develop nanotechnology.

• There is no regulation of research activity beyond that related to the evaluation of research proposals. Therefore, researchers have to use their personal responsibility towards human health and environmental security.

• Policies and regulatory framework of the different countries of the Andean region remain fragmented. The international calls to face the global challenges of nanotechnology research have had a limited effect upon them. Concern exists, because an accident caused by a non-regulated practice can have negative repercussions in the advancement of opportunities of application of convergent technologies, particularly nanotechnology.

• The Andean scientific communities are not producing necessarily independent and in-depth evaluations, in such a way that an informed public can support the definition of policies and regulatory approvals for the development and use of goods whose production will be based on a transformative or convergent technology. In general, these communities, in particular in the smaller countries, wait passively to be invited to consultations and dialogues, and rarely initiate them.

• The perception of science in the five countries is positive and constitutes an opportunity to advance in new policy decisions. The high percentage of people who think that the benefits of science are higher than the risks constitutes an important finding, and with the appropriate discussion and dialogue on policies, science can find an open atmosphere to development.

• In most of the Andean countries there does not exist an exact perception by the non-scientific groups of the opportunities and impacts of NBIC convergence, although an interest exists for the solution of problems based on science and technology. That is to say, the opportunity exists to explore a favorable perception of ST in favor of its own development and its applications. This perception is less favorable in developed countries.

• The non-specialized dissemination of nanotechnology in the mass media is not frequent and it is dispersed. The existing topics are in agreement, in general terms, with those of the applications being developed by the national groups of research, but the precision and clarity of the information transmitted to the public remain precarious in some of the most important media.

• The little knowledge and understanding of convergence existing in the scientific community of the smallest countries is also reproduced in the productive sector, which has a particular and dominant interest in biotechnology and computer science and little on cognitive science and nanotechnology. In this sector, there is an evident lack of conscience about NBIC convergence and its possible impacts.

• The absence of a publication culture, in the smallest countries, has created a lack of confidence of the researchers about whether or not their work is valuable for the international and national community. This has forced at the same time the establishment of poor quality journals, little dissemination, erratic regularity, and therefore of little academic use as the preferred means of communicating or disseminating research.

• In the process of communicating research results and disseminating information on transformative technologies, the "convergence challenge" is not well perceived in the academic - productive - governmental sectors. More specifically, there exists a low perception of the opportunities and risks of nanotechnology. Ethical and risk questions have not been raised and transmitted to the public, except in some articles in newspapers and magazines that have a sensationalist character.

• There exist in some Andean countries, a widely-spread vision that the reorganization of production will determine the future international economic insertion, and as such, it depends less on technology-based innovations than the resetting of the social and political actors. The function that the state plays in this process will express the new correlation of forces between social classes and the way in which the social and regional appropriation of the outputs is decided.

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This paper presents some of the more important results of the Project "Convergent Technologies in the Andean Countries: what is being done and what should be done about them?". The Project was executed between April 2005 and September 2007, under a grant from the International Development Research Center of Canada and the support of the Rockefeller Foundation. The Project was coordinated by the Institute of Social and Economic Studies of the Catholic University of Bolivia and was conducted by experts and assistants in the five Andean countries. The full version of the Final Research Report and other Project outputs can be found in the Project`s webpage (www.iisec.ucb.edu.bo/tecnologia).

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A list of researchers in four Andean countries can be found in the Final Research Report of the Project.
Forero and Gómez, 2007
The centers of Type-A are those that are recognized as scientific publication producers, with a minimum number of researchers with doctoral degrees and other attributes of centres of excellence.

NOELA INVERNIZZI

Nanotechnologies in Latin America: ReLANS Survey

Since the beginning of the current century several governments have allocated important resources into the research committed to develop nanotechnologies. The United States (US) launched its National Nanotechnology Initiative in 2001 with a budget of USD 500 million. Soon after, other developed countries launched their own Nanotechnology Initiatives, of which Japan and the European Union are the most important examples. Initially, most of the financial support came from public sources, but from 2005 half of the funds came from corporations and enterprises. This illustrates the attention that nanotechnologies have obtained as sources of innovation which can later be transformed into international commercial advantages (Foladori & Invernizzi, 2006).

Although most of the nanotechnology research and development (R&D) is conducted in developed countries, there are some semi-industrialized and a few developing nations using public funds to pursue nanotechnology research. China and India, for instance, are countries with advanced research programs in certain nanotechnology areas. In Latin America, Brazil was the first country to support the formation of nanotechnology research networks, since 2001. Other countries, such as Mexico, Argentina Colombia and Chile have been doing research with nanotechnology but in the recent years they have allocated even more resources.

It is possible to argue that nanotechnologies are potentially disruptive in social and economic terms. The multifunctional materials developed from nanotechnology have the potential to eliminate many industrial branches, like textiles or beverages of tropical origin such as coffee, tea or cocoa. The textile industry could be affected if the nanotechnology industry manages to fully develop intelligent nanocomponents with the capability to change according to sunlight or other weather conditions. This, of course, could mean that one garment can be adjusted to the needs and desire of the consumer. The industry of nutritional supplements is awaiting pending innovations of the nanotech sector to be integrated to the food industry. The latter is an example of several industrial sectors that can be amalgamated into one single manufacturing activity. It is clear that this will have deep-reaching effects on the social division of labor and employment. Therefore, the impacts and consequences have to be identified and researched by governments or civil society. Other matters of concern include the potential risks to health or the environment, which are still uncertain.

In November 2006, a group of Latin American academics worried about the potential impacts of nanotechnology on health and the environment, as well as the

1 ReLANS was launched at the III International Seminar of Nanotechnology, Society and the Environment organized by the Brazilian Nanotechnology Network on Society and the Environment.

social and ethical implications of its use, created a research network. On November 9th 2006, in the city of San Pablo, Brazil, the Latin American Nanotechnology and Society Network (ReLANS: www.estudiosdeldesarrollo.net/relans) was officially launched. ReLANS intends to create a forum for discussion and exchange of information that follows the insertion and the role of nanotechnologies in development in Latin America. Before the emergence of ReLANS, the topic had been mainly discussed from a "northern" perspective rather than from the views of the developing countries (Invernizzi, Foladori & Mclurcan, 2007). The contradiction between nanotechnology's potential impacts and awareness of the problem are the main motives behind the creation of ReLANS.

There are different interpretations about the role that nanotechnologies could play regarding poverty alleviation and development promotion. However, most of thee can be grouped into two predominant and contrasting positions. On one hand, we find what we call the *instrumental* position (Invernizzi, Foladori & Mclurcan, 2007), which puts emphasis on the use of the superior technical capability of nanotechnology to solve poverty and the problems of underdevelopment. This position portrays technology as if it were a neutral instrument, thus transferable to different contexts without problem. This position can be described as technologically determinist, because it identifies nanotechnologies according to their potential use to solve particular problems, such as the treatment of polluted water or for its desalinization; to capture and store energy; to diagnose and treat diseases, and, in general, to improve the living conditions of the population living in poverty. The latter is conceived without questioning or analyzing the economic and social forces under which these technologies are developed.

The other perspective we term *contextual*. It places emphasis on the social context in which a given technology, nanotechnology in this case, is produced, used or adapted. According to this position, technologies are not simple and neutral instruments but artifacts which materialize social relations, interests, political power, values and other social factors. In other words, technologies are socially conditioned. As such, nanotechnologies are the consequent result of the particular social structures from which they were created. Factors such as private production oriented toward profits, intellectual property rights, the concentration of innovation in developed countries and social inequalities are seen as key elements that can obscure the potential role of nanotechnologies in favor of development and the poor.

Nanotechnologies in Latin America may be identified within the contextual position. The authors argue that in order to make full use of the developmental potential of nanotechnologies to overcome poverty, it is necessary to go beyond simple adoption and diffusion. It is necessary to socially orient the development of nanotechnologies to this end. It is crucial to nurture their technological trajectory in correspondence with social objectives, such as the solution of problems related to poverty and the improvement of the living condition of the population.

To achieve its objectives, ReLANS took the initiative of creating a diagnostic of the development process followed by nanotechnologies. *Nanotechnologies in Latin America* is its product. From this effort, it is possible to analyze the political, social, economic, social, legal, ethical and environmental implications of nanosciences and nanotechnologies in Latin America.

Following the tendencies of the most developed countries, some countries in Latin America jumped on board the development of nanotechnologies. Although the amount of resources are much smaller in comparison with the extensive and growing expenses in the area that the US, Europe and Japan are allocating, they still represent a considerable effort at the regional scale.

Brazil takes the lead position in this area for the resources it has allocated the organization of the research groups and the scientific publications produced in the country. It was also the first nation in the region to launch a National Nanotechnology Program (Invernizzi, 2008). In 2001, almost at the same time that the US launched its *National Technology Initiative*, Brazil initiated the articulation of several efforts toward a national policy for the development of nanotechnology, such as an analysis of local capabilities and the organization of research networks, linking several institutions from all over the country and 350 researchers. Parallel to this, the Millennium Research Program of the Ministry of Science & Technology financed the creation of four institutes for nanotechnology research.

In 2004, the process was fortified with the incorporation of the Nanoscience & Nanotechnology Development Program (PDN&N) in the Pluri Annual Plan for Development (2004-2007) of the Ministry of Science & Technology. At the same time, the Industrial Technological and Trade Policy, launched in the same year, considered nanotechnology as a strategic area depicting it as "bearer of the future." Both policies were associated via the BrazilNano Network, which was created with the main purpose of linking academic research with the industrial application of nanotechnologies. In addition, 2004 brought the creation of the Binational Center of Nanotechnology Brazil-Argentina. In 2005, the National Nanotechnology Program was launched, with the allocation of more resources, consolidating the aforementioned policies in the area and with the core objective of using nanotechnologies to encourage innovation and competitiveness. In the same year, a new research fund allowed for the creation of ten new research networks, absorbing all previous efforts. In 2006, several nanotechnology research laboratories received financial support and the National Laboratory of Nanotechnology for the Agrobusiness sector was created.

In 2007, the Ministry of Science & Technology published the Action Plan 2007-2010, in which nanotechnologies had an important place and in which a call for policy implementation regarding the ethical and social impacts of nanotechnologies was opened (MCT, 2007). It is worth mentioning that despite the multidisciplinary approach that nanotechnology development has taken in Brazil, social sciences and the humanities had been thus far excluded from the discussion. Therefore, public policy had paid little attention to the political, social, economic and ethical implications of nanotechnologies, lacking the foresight to see the possible risks of using them.[2]

The path that nanotechnologies have followed in the case of Mexico, the second big player in the region, is somewhat different (Foladori & Zayago, 2008). The main difference is that there is no national plan or policy to direct the development of the nanosciences and nanotechnology. Paradoxically, the technology has been considered as one of vital importance, even strategic, as identified in 2002 in the Special Program on Science and Technology 2001-2006 within the National Plan of Development (Foladori & Zayago, 2007).

Despite the absence of an integral national policy of nanotechnology and combined with the consistent reduction in the budget destined to S&T, estimated at 0.4% of the GDP in 2005, several research groups were created. According to different estimates, there are currently between 300 and 500 scientists working in the area of nanotechnology, most of which are linked via bilateral or multilateral agreements and by the creation of national and international research networks. These networks incorporate the most important Mexican universities and research centers, creating bonds with the European Union, with some other Latin American countries, but mainly with the US, whose compelling influence is growing every year. The collaboration between Mexico and the US regarding nanotechnology development has been done by essentially three mechanisms: at the scientific-academic level (between research centers and universities); in correspondence with political and business interests (by establishing high technology parks within the framework of the North American Free Trade Agreement (NAFTA); and through scientific and military accords.

As the Brazilian case, the main justification to support nanotechnology development in Mexico is an increase in competitiveness and, at the same time, there is no concern about the social, economical, political and ethical implications, as well as the potential risks, of using nanotechnologies.

In Argentina, the interest of the government in developing the nanotechnology industry as it created the Argentinean Nanotechnology Foundation, resulted in a significant conflict between the scientific community and the parliament, a friction which was disclosed by the press (Foladori, 2005; Andrini & Figueroa, 2008). The government's proposal was put into question because it privileged a transnational company, Lucent Technologies, which was conducting clandestine military-related research and was dedicating public resources to the development of certain research areas.

Resulting from this discussion, the national nanotechnology policy and the

2 There are few official documents referring to the risks to health or the environment. One example is Order No. 64 (in which the creation of the Brazil Nano Network is proclaimed), published on December 1st, 2004 by the Ministry of Science & Technology, which states "or the study of the impacts on public policies, on ethics or on the environmental" (MCT, 2004).

FAN's aims themselves suffered a profound reorientation, incorporating in consequence other sectors of the scientific community. In addition, the accords signed by Lucent Technologies were omitted. Four priority research areas were defined and a grant call issued to finance the creation of research networks, from which four networks emerged. The entire purpose of the FAN is to develop N&N to support the productive sector.

Argentina has developed close collaboration schemes with Brazil with the objective of stimulating scientific knowledge, building human resources and contributing to the economic and social development of both countries. One of the immediate results of this partnership was the Brazilian-Argentinean School of Nanotechnology under the framework of the Binational Center of Nanotechnology Brazil-Argentina.

As in the previously-mentioned cases, the discussion of political, social and economic implications of the use of nanotechnology was absent during its development. However, the emergence of the discussion about the social implications of the application of nanotechnologies materialized after the FAN scandal. The denunciation opened the door to a rising of some ethical issues of nanotechnology development in the country such as the clandestine involvement of the US military. This, without any doubt, resulted in an opening to include a more critical position which began to appear in some programs in 2007.

In Colombia, as well as Brazil, Argentina, Mexico and Chile, research related to nanosciences started at the end of the 1980s or at the beginning of the 1990s. Nonetheless, public resources allocated have been, and still are, insufficient. Since 2005, despite the recognition by the institution in charge of endorsing S&T in Colombia (Colciencias) of the importance of nanotechnology as a strategic area, most of the encouragement has come from the Institute of Electrical and Electronics Engineers (IEEE). In 2005 the IEEE created the National Council of Nanoscience and Nanotechnology (CNNN) (Foladori, 2006).

In Chile, nanotechnology is integrated in the programs leading toward the creation of a knowledge economy (Foladori & Fuentes, 2008). This effort is evident in the S&T policies encouraged by the government and by the World Bank with the purpose of implementing the Millennium Institutes. These institutes urge the integration of the local business sector and the international networks of production of science and technology. The aim is to change the productive profile of Chile, from one oriented toward the export of primary goods to one highly intensive in the manufacturing of high technology goods. Although nanotechnology does not constitute a priority area to be encouraged within the scope of the plan to support Science, Technology and Innovation in Chile, it is present in some projects already being financed and executed.

Like in Argentina, some nanotechnology research activities linked to military purposes have been confirmed in Chile. This came to light particularly after the organization by the US Armed Forces of workshops which delivered contacts and meetings. The most important within this scheme is the creation in 2004 of the ITC-Americas headquartered in Santiago, Chile. ITC-Americas is one of the three International Technology Centers currently active worldwide, administered by the US Armed Forces (Foladori, 2006b).

Venezuela has not built a specific policy for the development of nanotechnologies and the possibilities for this to happen in the short term are, at the most, fairly scarce (De la Vega *et al*, 2008). The analysis presented about the Venezuelan capacity to produce nanomaterials, one of the areas with a promising growth potential in the years to come, illustrates the gap between this country and the most developed countries. It is argued that this gap will be the main obstacle to developing more aggressive programs to encourage the development of nanotechnologies in the country. Furthermore, this gap can be widened. However, it is worth mentioning that Venezuela since 2007 directed close to 2% of the GDP to Science and Technology. This figure is higher than Brazil's expenses (1.36 % of the GDP).

There are other countries in the region that have also coordinated some efforts to endorse nanotechnology development. In South America, Peru has some researchers working with nanotechnology in the main universities and the National Program on Science and Technology 2006-2021 recognizes the role of nanotechnologies for development. (Aguirre Bastos, *et al*, 2008). Researchers from Uruguay have not managed to persuade their government to place nanotechnology research as a priority. As a consequence, the public financial resources allocated into the area as of 2007 have been limited. Paradoxically, however, the private sector in Uruguay has been an active organizer of meetings to endorse nanotechnology development (Aguirre Bastos, et al, 2008). Additionally, some researchers from Uruguay have been incorporated into programs within the framework of the Binational Center of Nanotechnology Brazil-Argentina (Chiancone, et al, 2008). Ecuador has also allocated some financial resources into research programs undertaken by public universities but with scarce human resources.

In Central America, Costa Rica inaugurated the Laboratory of Nanotechnology, Micro-sensors and Advanced Materials (LANOTEC) with funding from the Foundation for the Cooperation Costa Rica-United States. Guatemala has followed the same path as Costa Rica but has not managed to build any significant infrastructure (Foladori, 2006; Mena Young, 2007).

In the Caribbean, Cuba is particularly interesting for the diversity of agreements with several European and Asian countries. Cuba has an important background in biotechnology research which makes it an important and outstanding player in the area of nano-biotechnology. What distinguishes Cuba from the other countries is the orientation of nanotechnologies toward the solution of specific problems of social development, as in the case of medicine and novel application procedures of nano-biotechnology in agriculture (Foladori, 2006).

What are, then, the development paths followed by nanotechnologies in Latin America that we can observe after this research? We can essentially group them around three trends. The first trend is a clear concentration of the development of nanotechnology in basically three countries: Brazil, Mexico and Argentina. These countries historically experienced in the region both a more advanced process of industrialization and a higher development of infrastructure dedicated to support public education and research. This concentration can, however, result in an increase in the south-south gap aggregated to the already impressive north-south gap regarding nanotechnology development. Nonetheless, this tendency can be overcome by the development of agreements and joint programs among the countries in the region with the purpose of endorsing the development of nanotechnologies. Some programs are stronger, at least at the moment, such as those between Brazil and Argentina, with some integration of Uruguay. Widening the scope and reach of these agreements would make it possible to make better use of the research infrastructure and human resources in the region. Furthermore, it would be possible to elucidate a better agenda with a focus on the economic and social needs.

Only two countries, Brazil and Argentina, have created national nanotechnology programs. However, the single aim of those programs is to use nanotechnologies as a tool to increase competitiveness. This is a second trend. The idea is to link knowledge to industry with the purpose of stimulating the productive sector, which has been historically characterized in Latin America by its little-to-no initiative toward innovation. The creation of national programs not only guarantees resources and stresses the importance of nanotechnology within the S&T national agenda, but also contributes to the establishment of national goals and delineates feasible research areas. For that reason, we see as essential the establishment of National Nanotechnology Programs to orient nanotechnology development in Latin America towards explicit goals of social development.

The third trend is the top-down approach followed by most countries in Latin America in order to train human resources in the area, starting from graduate programs. The formation of Centers of Excellence has been successful up to a point. However, there is a growing inclination toward linking research groups from different areas within the same countries and some efforts beyond international borders. Although the top-down approach could be successful for the formation of human resources in the short term, it does not seem to be sustainable in the long run for mainly two reasons: First, the approach represents a high risk to foment brain drain. Second, the quality of education at the basic and medium levels is lacking in Latin American countries, but essential to prepare a qualified working force, necessary for the productive application of nanotechnologies.

In addition to these trends we identified several critical points within latinamerican nanotechnology initiatives. One of them is the scarce, if any, reflection on the role of nanotechnologies in development and the mechanic conception of the relation between science, technology and society. The analysis of these issues becomes more important in the context of Latin America where problems such as social exclusion and the marginalization of employment and consumption of a significant part of the population prevail. The discussion acquires significance in two principal aspects: First, because nanotechnology policies should lead knowledge development in correspondence with the social demands of the countries and the region. The exclusive focus on stimulating national competitiveness neither guarantees the reduction of social inequalities nor the fulfillment of social demands. In societies that totally or partially exclude important social segments from consumption, it would be naïve to argue in favor of the market as a distributive agent. Some advances, however, are observed in this matter. The Action Plan 2007-2010 of the Ministry of Science & Technology of Brazil includes, as one of its four strategic aims, the advance of Science, Technology and Innovation for Social Development (MCT, 2007).

In second place, the nanotechnology revolution will dramatically change the current productive conditions. New changes are coming that would reshape the industrial sector, enterprises, the labor force, consumption and life overall. It is necessary to analyze the economic and social implications of the use of nanotechnologies to implement corrective policies when necessary. If in Latin America the development of nanotechnologies is disconnected from social needs and ignores the social implications of their use, it is likely to put into a more vulnerable position those who are already marginalized.

Another critical point observed from the experience of nanotechnologies in Latin America is the scarce consideration of the risks to health and the environment. These risks have to be studied, and then subordinated to regulations in order to protect the researchers working with them, the workers, the consumers, and, of course, the environment. There are some (slow) efforts in this regard. In the meeting of Nano-MERCOSUR, held in Argentina in August 2007, there was a panel discussing the risks. In Brazil, in the same year, high officials of the MCT at the IV Seminar organized by the Nanotechnology Network on Society and the Environment convened a meeting with social scientists and scientists from the natural and physical fields to discuss the issue. In Uruguay, the UY Nanotec Group showed interest in these issues in a session organized with members of ReLANS in 2007.

Finally, a third critical aspect of the policies and the actions leading to the development of nanotechnologies in Latin America is the scarce information and public debate about that development. There is also certain reluctance from the scientific community and policy makers to allow other sectors of society to take part in the discussion. In contrast, there are social movements, unions, small groups of agricultural producers and peasants organizing reunions to talk about how nanotechnologies might affect them. A technological revolution of this sort should not rest only in the hands of experts. It is necessary to democratize the discussion in order to orient nanotechnology development to benefit the majority of the population.

About these last points, it is worth mentioning the fundamental role of social scientists in the research and study of the political, economic, social and ethical aspects of the use of nanotechnologies. It is also necessary to emphasize an analysis of the risks because these are not only technical but also social in a very particular sense. To make advances in this way requires greater interaction among scientists from the natural and physical fields and social scientists to reflect on the issues and to support a responsible and socially-oriented development of nanotechnologies. This interaction should start now, in the training process of new researchers in the field.

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ReLANS was launched at the III International Seminar of Nanotechnology, Society and the Environment organized by the Brazilian Nanotechnology Network on Society and the Environment.

There are few official documents referring to the risks to health or the environment. One example is Order No. 64 (in which the creation of the Brazil Nano Network is proclaimed), published on December 1st, 2004 by the Ministry of Science & Technology, which states "or the study of the impacts on public policies, on ethics or on the environmental" (MCT, 2004).

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