Nanotechnology Public Policy in Latin America

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Abstract:
Many countries in Latin America have made nanotechnology a development priority in their public policy platforms. The main feature of these public policies is to provide support for nanotechnology research and development, aiming to forge ties between public institutions and universities and the private sector, to boost innovation and competitiveness. These public policies do not take into account the global context of strong capital concentration in which nanotechnologies emerge, and which makes it difficult to be competitive within the framework laid out by these public policies to develop these technologies. This paper analyzes the direction of public policy in the international context, and also suggests policy alternatives.
Key Words: Nanotechnology, public policy, research and development, science and technology.

Date received: October 2, 2015.
Date accepted: March 11, 2016.

Introduction

Nanotechnology refers to a range of techniques used to manipulate matter at the atomic and molecular scale. Its importance resides in the fact that materials on the order of between 1 and 100 nanometers display different physical, chemical, and biological properties than the same materials would at a larger magnitude. Gold, which is not reactive on the larger scale, becomes reactive at the nanoscale and is used to manufacture sensors; carbon as graphite is soft, but carbon in nanotubes is harder than steel. Practically all chemicals behave differently at the nanoscale. This particularity permits vast modifications in the functionality of products. As a result, nanotechnology has come to be seen as the next industrial revolution (VVAA, 2014).

Unlike previous technology revolutions, driven by power (the Industrial Revolution the invention of electricity, the internal combustion engine), information processing and transmission (ICT – information and communication technologies), or living beings (biotechnology), nanotechnology is centered on matter in a broader sense, because its potential resides precisely in the potential of harnessing new properties of materials. This is an Industrial Revolution that is permeating all economic sectors more or less simultaneously, because all sectors use some type of material, and these materials can be manipulated at the nanoscale to develop new features.[1]

This Technology Revolution is recent, because it required the development of atomic microscopes at the end of the 1980s and the 1990s in order to precisely measure the new properties of materials, which in many cases were already known.[2] Moreover, it was the launch of the National Nanotechnology Initiative in the United States in 2001 that spurred many other countries to begin investing in nanotechnology research and development in order to keep up. Nanotechnology is the Technology Revolution of the twenty-first century. According to the consultant Científica,

> Since the US National Nanotechnology Initiative was announced in 2000 almost every developed and developing economy has initiated national nanotechnology programs. The world's governments currently spend $10 billion per year on nanotechnology research and development, with that figure set to grow by 20% over the next three years (Cientifica, 2011).

Various reasons make it understandable why no country can be left out of this science and technology revolution. In economic terms, countries that do not produce their own nanotechnology are already importing nanotechnology products, in many cases without even being aware that they are doing so. This will produce an impact on the social division of labor and the formation of value chains, as well as undesired effects, such as potential health and environmental risks.[3]

Scientifically and technologically speaking, researchers from diverse fields are tracking the latest developments and publications and are under pressure to educate themselves about these new nanosciences and technologies. The Internet, online scientific journals, conferences, and research networks are ensuring that researches can be aware of what is happening in the international science discussion, regardless of where they are physically located.

At the political level, international bodies such as the Organization of American States (OAS), the Organization for Economic Cooperation and Development (OECD), and the World Bank (WB) have placed nanotechnology on their development cooperation agendas as a priority development area (Drilhon, 1991), alongside ICTs and biotechnology (Foladori, 2013).

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[1] Technologies that can be applied to a vast range of economic sectors are called general purpose or enabling technologies (Bresnahan and Trajtenberg, 1995; Shea, Grinde, and Elmslie, 2011).

[2] The invention of atomic microscopes facilitated and drove forward research in nanotechnology (e.g., the scanning tunneling microscope (STM) – Binning and Rohrer, 1981, and the atomic force microscope (AFM), 1985).

[3] There is abundant literature discussing the potential risks of nanomaterials for health and the environment, to such an extent that there is now a specific field of toxicology referred to as "nanotoxicology," and the top occupational health agencies in the European Union and the United States have safety guidelines for handling nanomaterials. See, for example (Colvin, 2003; Donaldson, Stone, Clouter, Renwick, and Macnee, 2001; Maynard, 2007; Oberdörster, Oberdörster, and Oberdörster, 2005; Poland *et al.*, 2008).

In light of this situation, it is increasingly important to reflect on how countries in Latin America are taking on this technology revolution.

Latin America Joins The Nanotechnology Revolution

Now well into the second decade of the twenty-first century, many countries in Latin America have set up nanotechnology research groups, while their governments have pointed to nanotechnology as a priority development area. Two trends have converged to lead to this outcome. On the one hand, the natural advancement of the physical and chemical sciences, which have been researching the properties of matter at the nanoscale since the 1990s. At least in some countries, such as Brazil, Mexico, and Argentina, materials science research at the nanoscale did not come about due to any specific policy in this regard. Scientific publications from the 1990s demonstrate this, although at that time the term "ultrafine particles" was more commonly used than the current nanomaterials (Robles-Belmont and Vinck, 2011). On the other, international organizations have exerted pressure, since the end of the 1990s, to make nanotechnology a priority area for science and technology development, together with ICTs and biotechnology.

The trend towards the homogenization of science and technology (S&T) public policy is longstanding (Albornoz, 1997; Velho, 2011). International institutions such as the Organization of American States (OAS), the Inter-American Development Bank (IDB), and the United Nations Organization for Education, Science, and Culture (Unesco), have long promoted common S&T policies in Latin America. The WB was a pioneer in this sense, helping to fund the Millennium Project in nanotechnology (Foladori and Fuentes, 2008; Macilwain, 1998). In addition, the OECD lobbied to restructure the entire science and technology sector in Mexico (OCDE, 1994), while the OAS (COMCYT, 2004) made nanotechnology a priority area in it is advising to various countries throughout the region (Foladori, 2013).

This does not mean that these policies have been applied equally in all cases, but in the majority of countries, there are some attributes in common as a result of these guidelines. One example of this isomorphism is the declaration of nanotechnology as a priority development area. Table 1 displays the year in which each country launched its policy to support nanotechnology or add it is a priority development area.

Not all countries have accompanied these declarations of interest with financial support, but many have done so, at least the larger of the countries. The governments of Brazil (Invernizzi, Korbes, and Fuck, 2012), Argentina (García, Lugones, and Reising, 2012; Spivak L'Hoste *et al.*, 2012), and Mexico (Záyago and Foladori, 2012) have funded research networks and multi-user labs, made available infrastructure and equipment, supported research/production clusters, and promoted competitions, frequently through public-private partnerships for nanotechnology research.

Although it is difficult to estimate public funding, analysts have cited some figures. The figure given for Argentina is generally in the realm of 50 million dollars between 2006 and 2010 (Salvarezza, 2011). For Brazil, around 190 million dollars between 2004 and 2009, as stated by the Ministry of Science and Technology (Invernizzi, Korbes, and Fuck, 2012), not counting funds from the states themselves, which only in the cases of San Pablo, Minas

Gerais, and Rio de Janeiro would be more than 60 million dollars in the same time period. In Mexico, estimates suggest approximately 60 million dollars between 2005 and 2010 (Takeuchi and Mora Ramos, 2011), and in Chile, 30 million dollars between 2005 and 2010 (Zumelzu Delgado and Zárate Aliaga, 2011).

Table 1. Public Policies to Support Nanotechnology or Adding Nanotechnology as a Priority on Development Plans in Select Latin American Countries

Year	*Country*	*Support Institution*
2000	Brazil	Ministry of Science and Technology
2001	Mexico	National Science and Technology Council
2003	Argentina	Secretariat for Science and technology
2004	Colombia	Administrative Department of Science, Technology, and Innovation
2004	Costa Rica	National Science and Technology Research Council
2005	Guatemala	National Science and Technology Council
2005	Ecuador	National Science and Technology Secretariat
2006	El Salvador	National Science and Technology Council
2006	Peru	National Science, Technology, and Technology Innovation Council
2008	Dominican Republic	State Secretariat for Higher Education, Science, and Technology
2009	Uruguay	Ministerial Cabinet for Innovation
2010	Panama	National Secretariat of Science Technology, and Innovation

Source: Created by the author.

The commonalities among the policies implemented by Latin American countries in nanotechnology matters (e.g., favoring support for the private sector, oriented towards boosting competitiveness, encouraging the creation of spin-offs from public universities) should not, however, conceal their differences. In Argentina, for example, public funding is explicitly allocated to small and medium-sized enterprises (FAN, 2012). In Brazil, there is a more diversified approach, seeking to integrate funding with national thematic laboratories, making this policy, as such, more aligned with national development strategies (Invernizzi, 2010; Invernizzi, Hubert, and Vinck, 2014). In Mexico, there is a clear stance towards funding with no connection whatsoever to national development projects (Foladori *et al.*, 2012). However, despite the differences, there is a common orientation, in many cases the same as that promoted by international bodies, such as the OECD or the WB (Foladori, 2013). However, what is the explicit justification behind declaring nanotechnologies to be a priority development area and allocating public funding towards this field? In response to this question, there is once again a single and common response despite rather divergent realities: to raise competitiveness (Brazil (GT 2003: 8), Mexico (CONACYT, 2008: 25), Argentina (República Argentina, 2009)). This rationale assumes that developing sophisticated technologies (high-tech), will boost a country's competitiveness on the international stage, which will engender development and improve welfare. However, this rise in competitiveness is no guarantee of welfare, as has been demonstrated in many other cases. Mexico, for example, saw its competitiveness rise right after signing the North American Free Trade Agreement in 1994 and up until 2000, with a parallel increase in poverty and social divergence (Delgado Wise and Invernizzi, 2002). The official discourse also claims that new technologies will bring with them new sources of jobs, but fail to mention that the more high-tech industries become, the fewer jobs they create. Nor does the discourse mention how this type of technology can be disruptive, leading to unemployment and the shuttering of less competitive companies, which are naturally those that employ more people (Hecker, 2005).[4] Nor does the official line acknowledge that, given the level of disaggregation and globalization of productive chains, participating in these chains in material terms does not guarantee a payoff in value received (Gereffi, 2014).

The essence of this Technology Revolution is that the change is happening to the way raw materials behave. It is enough to merely introduce nano-raw materials, which in material terms of mass or volume may be insignificant, but whose final product will be extremely different from the old competition. In terms of value, however, the situation is different. The value added by incorporating nanoparticles may be completely marginal with respect to the final value of the product. Although this will depend on each specific value chain, the fact remains that the final product of nanotechnology is substantially different from the traditional competition, because it incorporates a negligible amount of nanomaterials, which in terms of value, may be a minimal difference.

Already in 2004, Lux Research, a financial consultant in the nanotechnology field, was estimating the next value ratio between the three main stages of the value chain pursuant to the volume of products in the market (see Table 2).

Table 2. Value of Products on the Market by Stage in the Value Chain[5]

[4] In the case of the United States, "Employment in high-tech industries increased 7.5 percent over the 1992–2002 period, compared with 19.7 percent for the economy as a whole, and accounted for 5 percent of total employment growth" …. "During the same period, high-tech employment declined from 12.2 percent to 11 percent of total employment. Projections for the 2002–12 period show high-tech employment continuing to grow more slowly than the economy overall, at 11.4 percent compared with 16.5 percent" (Hecker, 2005: 59).

[5] Based on a model with 42 products (Lux Research, 2004).

Stage in the Value Chain	Value in USD in 2004 (millions)	% of Added Value per Stage
Nanomaterials	134	1.1
Nanointermediates	851	7.1
Nanoenabled final products	12 001	100.0

Source: Lux Research, 2004

Although these are rough estimates based on the total market, Table 2 shows that the value of nanomaterials is about 1% of the final value of the product. The same consulting firm estimated that it would fall to half (0.5%) in the next ten years as nano-raw materials become cheaper and are made in mass production. One eloquent example of this concept is carbon nanotubes. The cost of one gram of carbon nanotubes has dropped from over 1,000 dollars at the beginning of the twenty-first century to less than 100 a decade later (Rogers, Adams, and Pennathur, 2011; University Sains Malaysia, 2012).

However, despite adding very little value to the final product, the contribution of nanomaterials is crucial, as it endows the end product with a novel characteristic that can make it disruptive. Self-cleaning glass, nutraceutics, longer-lasting tires, more efficient solar filters, nano-ceramics capable of replacing glass, and aluminum packaging are all changes that are having a radical effect on conventional industries; however, they add very little value to the end product.[6]

The fact that the value of nanomaterials is marginal with respect to the final value of the product requires a careful consideration, for each product, of how the value – and not only the material – behaves in the value chain. The received wisdom of nanotechnology development support programs is that they will boost competitiveness, but if the country in question is located in a stage of the value chain where the added value is marginal, even if they take part in producing final products with nanotechnology, they will not necessarily benefit economically from doing so. The case of the Apple iPhone is particularly fitting. It is manufactured with pieces made in various countries, but the assembler only earns 6.54 dollars on a final sales price of 169.41 dollars:

> Paradoxically, China does not create or capture most of the value generated through its value chain exports. In fact, as more types of intermediate goods are traded within global supply chains, the discrepancy is growing between where final goods are produced and exported and where value is created and captured. For example, Apple's iPhones are entirely assembled in China by a Taiwanese contract manufacturer (Foxconn) and exported to the US. When a traditional measure is used, which assigns the gross export value of the product to the exporting country, the unit export value of iPhones from China is $194.04. Of this, only $24.63 is imported content from the US, meaning that every iPhone imported into the US results in a US balance of payments deficit of $169.41 (Figure 2). However, this does not mean that China benefits from a trade surplus of $169.41 for each iPhone it exports, since the value added in China is only $6.54 per phone (Gereffi, 2014: 20-21).

[6] Many other examples of replaced materials and disruptive materials can be found in Urlich (2003).

As such, participating in nanotechnology value chains does not necessarily guarantee the companies or countries in question that they will benefit from these new technologies. In order to ride the nanotechnology wave, it is not enough to merely have public policies that promote nanotechnology, even when there is funding place, if there is a lack of planning about what products, what fields, and under what conditions to develop nanosciences and nanotechnology. And in coming up with national policies it is essential to understand the international context.

The International Nanotech Context

The nanotech revolution is generally perceived as being capable, with a certain degree of government support, of engendering development in developing countries. The Science and Technology Working Group of the United Nations Millennium Project has suggested that the development of nanotechnologies should be oriented, in these countries, towards such strategic sectors as drinking water, medicine, and energy, to help achieve the Millennium Development Goals (Juma and Yee-Cheong, 2005; Salamanca-Buentello *et al.*, 2005). In the same sense, the editorial “Confronting Global Poverty,” written by the Council of Science Editors for the second issue of *Nature Nanotechnology* (2007) asserted that developing nanotechnology in such specific areas as water and medicine could entail a significant improvement to the lives of the poor.

Beyond the good will of the U.N. project, the problem is also present in the production processes for water filters or nano-medicines. The same as in nano-energy or in any other field, companies depend primarily on the purchase of the nano-raw materials used to manufacture the filters (e.g., carbon nanotubes), energy capturers (e.g., titanium dioxide), medicines (e.g. dendrimers), which are strongly concentrated in the hands of international chemical corporations, and, depending on the purpose, may require intermediate processes to make the raw material functional for the final product. The result is that the vast majority of nanotechnology companies in Latin America are located in the latter stages of the value chain, in “adding” the functionalized raw material to the final product. In Mexico, recent research demonstrated that over 50% of nanotechnology companies are located in the last phase of the value chain and that only 4% of companies are producing or researching some type of instrument related to the process of designing and/or manipulating nanotechnology (Appelbaum *et al.*, 2016). In Argentina, nearly 45% add nanomaterials to final products (Zayago Lau *et al.*, 2015). What is certain is that nanotech companies, even those oriented towards products that might be thought of as closer to meeting social needs, are trapped in a global value chain context that makes them dependent on the external conditions of chemical corporations in terms of raw materials, and on a half dozen or so large sophisticated technical equipment manufacturers (e.g., microscopes). In the absence of a government policy to vertically integrate value chains for nanotechnology, it is unlikely that they will be able to play a real role in terms of social development.

Besides breakdowns in the value chain, in capitalist societies there is a dual metamorphosis preventing products from directly satisfying the needs for which they were created. The first is that these products must get to the market, which means their prices must recoup the cost of production and still provide a profit to the business owner. When there are alternative investment options that offer greater returns, production shifts towards those sectors. Neglected diseases are a very eloquent example of important areas of research that have been sidelined due to market reasons. The second metamorphosis is that consumers must have the purchasing power to buy the goods. Once again, this is not the case for millions of people in Latin America and around the world. Due to these two metamorphoses, in a market economy, technology development proposals limited to timidly suggesting or subsidizing the production of strategic products that satisfy immediate needs are nothing more than a declaration of good intent.

In much of the official nanotech discourse, and sometimes in the funding discourse, as well, there is the idea of nanotechnology as a way to leverage development. In some cases, the suggestion is that new small and medium-sized enterprises will emerge that give momentum to the economy.[7] This image is taken from what happened with the ICT and biotech revolutions, where it was true to a certain extent. However, the situation in the middle of the first decade of the twenty-first century is not the same as it was in the 1990s, when other technology revolutions were booming. This different context is key to understanding that without public policies that take it into account, it will be very hard for the development of nanotechnology to contribute, in Latin American countries, to improving living conditions for the population, not to mention boosting competitiveness. Thus, what is the difference between the 1990s as compared to 2004 and since in terms of the development of nanotechnology? The principal difference resides in the concentration of global capital.

Estimates proffered by various international consultants signal that the global market of nanomaterials products surpassed three billion dollars in 2014. One of these reports, from BCC Research, placed the estimate as high as 3.4 billion, with the majority of the market in the United States and the Asia-Pacific region (BCC Research, 2014). However, these data estimate the sale of all products containing nanomaterials; when only nano-raw material sales are taken into account, which are the point of departure for any nanotech industry, the concentration of chemicals in the hands of just a few corporations is alarming. Below are data on the concentration of the production of carbon nanotubes and titanium dioxide, two of the most versatile nano-raw materials, as they are used in diverse fields, and among some of the highest production in terms of physical quantity, but where just a handful of companies produce over 80% of total worldwide amounts. This concentration in the hands of a few chemical corporations should not be surprising, as the production of homogeneous nano-raw materials, able to be incorporated into industrial processes, is costly and requires sophisticated infrastructure.

A little more than a decade on since the nanotech product market started to really take off, capital concentration in large corporations is already apparent. The nanotech consultant Cientifica wrote: “Recently, the number of nanomaterials producers has declined as this production has become centralized and multinational chemical companies dominate the market” (Cientifica, 2008: 27).

Despite the fact that nanotechnology research has been conducted consistently since the 1990s, it was not until the twenty-first century, thanks to government initiatives that injected public funding into research, that there began to be a boom in research and development and the sale of products including nanotechnology. The fact of having entered the market in the twenty-first century is in and of itself significant, if we consider that the degree of capital concentration in the global economy today is much higher than it was at the time of the ICT

[7] The Argentina Nanotechnology Foundation (FAN) makes explicit its support to SMEs.

and biotech revolutions in the 1980s and 1990s. One of the most notorious consequences of the liberalization and globalization of the past two decades is the concentration of capital in the hands of few and powerful transnational corporations in the majority of economic sectors. In the United States, for example, in 1987, 25% of manufacturing industrial sectors were controlled by four companies that accounted for 50% or more of sales; by 2007, this percentage had risen to 38% (Foster, McChesney, and Jonna, 2011). The 1990s were the boom of globalization and, with it, the rapid concentration of capital. In the context of the emergence of nanotechnology, practically halfway through the first decade of the twenty-first century, the world saw the highest levels of capital concentration than in any other period prior.

Capital concentration is supported by diverse regulatory and institutional processes, such as the protection of intellectual property rights. These processes are time-consuming, expensive, and susceptible to endless legal challenges,[8] which makes it difficult for small and medium-sized enterprises to handle them and therefore favors concentration. Patent applications to the World Intellectual Property Organization went from 20,000 in 1990, to 90,000 in 2000, and to over 140,000 in 2006 (OMPI, 2007).[9] Another aspect related to capital concentration is the growth of the financial arms of large corporations, which have launched venture capital funds to finance small and medium-sized enterprises, thereby controlling their destinies (as strategic investors), whether through mergers and acquisitions, or financing that includes clauses to gain seats on these companies' boards. All of this means that the owners of these new enterprises are not trying to grow or expand but rather to sell their companies as soon as they gain some recognition in the market. Just when start-ups finally get their footing, which tends to happen between two and five years down the road, they tend to be sold to large corporations or merged with other big companies. This is a two-sided trend. On the one hand, large corporations, rather than investing in training qualified staff, can cherry-pick already-proven human resources off the market (Graham, 2005).[10] On the other, the costs of maintaining high-tech companies – with the exception of a few fields – have risen, in administrative, legal, and material terms,[11] and nanotech equipment and facilities require large investments.[12]

[8] According to the American Intellectual Property Law Association (AIPLA), the cost of litigating a patent is on average 2.6 million dollars, which has risen 70% since 2001.

[9] According to data gathered by the Organization of Ibero-American States (OEI) in 2009 on the World Intellectual Property Organization, between 2000 and 2007, 42% of patents were in the hands of the top 10 biggest corporations around the world, including Bayer, Philips, and 3M, and some United States universities with vast economic power, such as the University of California and the Massachusetts Institute of Technology. In terms of countries holding patents, the concentration is even more clear, with the United States accounting for more than 60% (OICTel, 2008).

[10] "Large companies (public and private) are increasingly setting up affiliated venture capital funds to invest in high-tech start-up companies" (Graffagnini, 2009: 257).

[11] The cost of defending patents and intellectual property has grown significantly and is another reason that start-ups merge or sell (McNeil *et al.*, 2007).

[12] "'With the exception of about half a dozen companies, every tech startup is for sale,' said Jim Moore, founder and CEO of J Moore Partners, a firm that specializes in tech M&A. According to a recent study by Ernst and Young, the volume of M&A in the technology space surged 41 percent in 2011, reaching levels not seen since the dot-com boom" (Farr, 2013).

Another contextual factor behind the rapid concentration of capital in nanotechnology was the 2008 crisis. Nanotech products and companies with nanotech research and development departments had been founded a mere three or four years before the crisis, when venture capital was flowing. But the 2008 crisis saw venture capital dry up except in those cases where fast returns were evident (NCMS, 2010: 20, 23). In this sense, the economic circumstances further strengthened capital concentration. The National Center for Manufacturing Sciences' 2008-2010 study on nanotech marketing strategies in 2008-2010, spoke of the so-called "valley of death," or the challenges involved in moving from research and development to industrial production, and commented on the impact of the crisis on capital concentration and control of the value chain, through the purchase or merger of small enterprises with large ones and the vertical integration of the value chain:

> Stronger nanotechnology companies exploited the industry downturn by investing in or acquiring under-valued technology partners, and vertically integrating with material suppliers and intermediate processors, thereby increasing their control of the product/process value-chains (NCMS, 2010: 20).[13]

The consulting firm Lux Research also asserted that the crisis favored large corporations to the detriment of start-ups:

> The economy offers a margin to large corporations, and challenges start-ups. The economic downturn invites those who benefit with good resources to renovate and reposition their technology portfolios, beating down and knocking out the smaller companies by cheapening their value. Start-ups short on cash need it as a priority to survive while markets recover (Lux Research, 2009).[14]

Unlike with ICT and biotech, the Nanotechnology Revolution was born of an economic age of higher concentration and was rapidly co-opted by large corporations, making it difficult for small and medium-sized enterprises in developing countries to get on board the nanotechnology revolution without their companies being bought, merged, or pushed out of business by larger firms in just a few years. Despite the fact that the cost of producing some nanomaterials can be relatively accessible for small enterprises, the leap to industrial production is not, due both to the sophistication and cost of equipment, as well as difficulties involved in producing homogeneous raw materials.[15] The result is that many countries

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[13] Based on a survey of 270 nanotechnology executives.

[14] Carbon Nanotechnologies Incorporated (CNI), a company founded by the Nobel Prize winner Nobel Smalley, co-discoverer of fullerenes, was sold in 2008 for 5.4 million dollars, when the initial offering price was 180 million (Cientifica, 2008).

[15] For many nanomaterials, there are technical requirements that favor the concentration of capital. The ability to consistently supply products with exactly the same characteristics requires sophisticated technical procedures that only large corporations can guarantee, because any minor variation in the product will render it non-functional. In this regard, the consulting firm Cientifica noted: "Crucially, the big suppliers have strict quality control procedures. That means if Boeing wants to use a new nanoparticle-based composite, it can be sure that it can buy the same thing next week, next year and in 10 years' time and that companies such as BASF will still be in business next month. This ability to buy large

finance small nanotechnology enterprises pursuant to the concept of research and development, but in reality, many of these companies will be sold to large corporations, rendering dubious their true role in development.

Although there are no precise data in this regard, it is possible that the leading nanomaterials available on the market are carbon nanotubes and fullerenes, titanium dioxide, zinc oxide, and nanosilver,[16] as ranked by the Center for Knowledge Management of Nanoscience and Nanotechnology (CKMNT) in India in 2010 (Patel, 2011).

Carbon nanotubes are one of the most versatile nanotechnology raw materials with applications in diverse economic fields.[17] Carbon nanotubes (the immense majority are multiwall carbon nanotubes), represented, according to CKMNT, 28% of the nanomaterials market in 2010 (Patel, 2011). Industrial production of carbon nanotubes is extremely concentrated in the hands of a few corporations. The CKMNT report for 2010 calculated that 66% of production was in the hands of just four companies, which produced over 100 tons annually each (Showa Denko, CNanotec LTd, Nanocyl S.A., Bayer MaterialScience AG) (Patel, 2011).

The same that is happening with carbon nanotubes is true of other nano-raw materials that make up the majority of the market. Titanium dioxide nanoparticles are another example. According to Future Markets Inc. (2011), 50,400 tons were produced worldwide, but the majority of production is concentrated in a handful of chemical corporations (DuPont, Nanophase, NanoGram, Advanced Nanotech, Nanogate, Degussa/Evonik, AltairNano) (Robichad *et al.*, 2009). According to a non-exhaustive review by *Nanowerk,* nearly 50% of companies that supply nanotechnology raw materials are located in the United States (Nanowerk, 2014).

Nanotechnology Public Policies In Latin America

In Latin America, practically all nanotechnology research and development funds are public. In some countries, such as in Brazil, Mexico, Argentina, and Chile, there are funds explicitly allocated for nanotechnology (Foladori and Invernizzi, 2013). In other countries, researchers must compete in contests alongside other research fields or topics. However, the prevailing standard is that funding is short-term and favors centers of excellence. These funds are generally meant for one- to three-year time periods. The idea is for the government to give the initial push and then for private enterprise to step in, from that point forward, in investing in nanosciences and nanotechnology research and development and incorporating this knowledge into productive processes to get products on the market. However, with nanotechnologies, they are facing an unknown market, lacking articulated production chains

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quantities of well-characterized materials is what will bring nanotechnology to market" (Cientifica, 2008: 28).

[16] With the exception of coal and silica, which are considered "traditional" nanomaterials and constitute the majority of the nano-raw materials market.

[17] One indicator of the scope and breadth of carbon nanotubes is that out of all nanotech patents granted by the U.S. Patent and Trademark Office in 2009, carbon nanotubes accounted for 48% (Heines, 2010).

and mechanisms to access credit in an operating market. These are new products, frequently disruptive in the sense that they fulfill multiple functions and are not exactly identical to those already on the market. In addition, these products must create new chains, ranging from the purchase of raw materials to the process to incorporate nanoparticles or nanostructures into existing final products. There is no historical market experience in this realm, so it is very difficult for private enterprises to invest in research and development and in production in light of these conditions of uncertainty.

Considering that substantial public funding for nanotechnology is a relatively recent development (since approximately 2004 in Brazil, 2006 in Argentina, and 2007 in Mexico), it is very hard to estimate the results of these policies, especially when only the first preliminary studies on nanotechnology products in Latin American markets are coming out. However, the majority of countries in Latin America have research groups and, to some extent, sophisticated technical equipment that will allow them to compete in research and development at the international level. Although there are no official records about nanotechnology research activities in Latin American countries (the closest is the information available in the database from CNPq research groups in Brazil), a research study sponsored by the EU 7th Framework Programme with the participation of Latin American teams surveyed nanotechnology research groups in seven Latin American countries in such topics as nano-water, nano-energy, and nano-medicine, and found groups with the capacity to compete in the international arena in these three areas.[18]

However, the public policy orientation towards promoting the insertion of this mainly public research with private enterprises presents many “valleys of death” that are standing in the way of this transition. It is extremely hard to connect various enterprises at the production level with commercialization and end consumers. This leap between production and commercialization is known as the “valley of death.” Contradictorily, many Latin American countries have a sector in science and technology that is not being exploited by public policy. These are sectors where state control is quasi or entirely monopolistic. Despite the privatizations of the 1980s and 1990s, many countries still have public sector involvement in the production of materials and services, frequently in areas related to drinking water, energy, health, and transportation. These sectors could be used to integrate research and development and drive production under the total or quasi total control of the value chain, preventing the formation of these “valleys of death” that the market generates. Sectors such as drinking water, energy, public transportation, and public healthcare have mechanisms to get the final products to the consumers, without the need to go through the market, or going with subsidies. A project of this nature would organically integrate research groups with production processes and consumption. However, the orientation of the majority of policies, which favor private enterprise, could, in the case of nanotechnology, run up against a strong subordination of transnational companies.

Conclusions

[18] See *NMP-DeLA. Nanosciences, Nanotechnologies, Materials and New Production Technologies. Deployment in Latin American Countries*, FP7-NMP-2013-CSA-7, <http://cordis.europa.eu/ project/rcn/108951_en.html>

The majority of Latin American countries do have research groups qualified in nanosciences and nanotechnology. Many of them have sophisticated teams and are on par with international centers of excellence (Foladori, Invernizzi, and Záyago, 2012). These groups, research centers, and specialized labs sprung up over the first decade of the twenty-first century.

Nanotechnology public policy in Latin America has tended to encourage these research groups joining up with private enterprise, or even generating start-ups. The success of this sort of path is highly debatable, given the international context in which nanotechnology has emerged. Unlike what happened with ICTs or biotechnologies, the degree of capital concentration worldwide in the early 2000s, when nanotechnology burst onto the scene, was much greater than one decade earlier.

Large corporations have co-opted the principal value chains for nanotechnology. It is difficult to join a value chain without falling to a marginal spot in terms of economic benefits. Moreover, the productive orientation of large international corporations is not closely intertwined with the needs of the majority of Latin American countries, even if in some cases it could raise their international competitiveness.

Latin American countries still have quasi or fully monopolistic state enterprises in such realms as public health, energy, water, or transportation, at least in some nations. In these cases, there is the advantage of being able to set up vertically integrated production, ranging from production to consumers themselves. Research and development could be connected with production and consumption, preventing the "valleys of death" that the market generates for production. Unfortunately, this is not the path that science and technology public policy has taken.

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