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State of the art: nanotechnology industry in Mexico

Área de investigación: Entorno de las organizaciones

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STATE OF THE ART: NANOTECHNOLOGY INDUSTRY IN MEXICO

Abstract

Nanotechnology is a multidisciplinary science viewed as one of the strategic areas for national development and its promotion around the world by the government, education entities and industry is undeniable. The purpose of this work is to recommend the way in which private and public sectors must interact and participate to define the better corporate strategy that enables them to succeed in this dynamic industry. To be able to state out these recommendations it is necessary to identify and analyze the particular characteristics of Mexico's Nanotechnology Industry. This analysis is carried out through Porter's Five Forces Analysis, Triple Helix Model and SWOT Analysis.

Keywords: industry analysis, nanotechnology, triple helix.

Introduction

Nanotechnology has been promptly suggested as a disruptive science that will help to solve several problems in our society. This science has its bases in chemistry, physics, mechanics, electronics and other science and engineering branches. This worldwide trend is a new opportunity for the creation of top tech jobs and the development of a whole industry in Mexico.

The contemporary wide use of the "nano" prefix has been denounced by a large sector of the scientific community (Loeve, 2010). They accuse that the term has been oversold, denounced, and discussed to the point that it sounds like a scientific marketing term. For many people without scientific education or background, "nano" has become a magic prefix to sell. For this reason, it is important that in this work we clarify the meaning of Nanotechnology we will use.

Steffi Friederichs, researcher of the Organization for Economic and Co-operation and Development (OECD) has carried out the job of propose and revise the statistical definition for Nanotechnology, which we will use. Its definition states:

> *The understanding of processes and phenomena and the application of science and technology to organisms, organic and inorganic materials, as well as parts, products and models thereof, at the nano-scale (but not exclusively below 100 nanometers) in one or more dimensions, where the onset of size-dependent phenomena usually enables novel applications. These applications utilize the properties of nanoscale materials that differ from the properties of individual atoms, molecules and bulk matter for the production of knowledge, goods and services, like improved materials, devices, and systems that exploit these new properties.* (Fiederichs & Beuzkom, 2018)

Regarding nanotechnology, several of the terms that will be found on literature are: *nanomaterial*, *nanoelectronics*, *nanomedicine*, *nanodevices*, *nanobiotechnology*, etc.

Furthermore, Nanotechnology is believed to have a great economic potential. For this reason, about 60 countries are currently investing public funds for its research and development. Between 2000 and 2014 the global government spending was estimated to about $100 billion USD, while private investment was worth about $150 billion USD (Flynn, 2014). Despite these worldwide investments, to date, the revenues of public and private spending in nanotechnology is relatively modest. Some of the products that have already seen the market and gone to the customer are water-resistant coatings, self-cleaning glass, nanoporous filters, carbon-based (graphene) materials, controlled drug delivery systems and smart textiles.

With all these "Nano"-World hype, Mexico has not stayed behind for much and is among the principal Latin-American countries searching to enter the nanotechnology contest. The aim of this work is to provide insight to the specific circumstances and characteristics of Mexico's developing Nanotechnology Industry through an industry analysis that would bring vision to public and private corporations, as well as entrepreneurs (individuals) to enable them to develop in this dynamic and relatively new industry.

Theoretical Framework

In order to analyze and further make recommendations for the Mexican Nanotechnology Industry, it is necessary first to assess its current competitive strategy and the conformation, integration and rivalry of the different performers in the industry. Two theoretical frameworks of

competitive strategy are the Five Forces Analysis (Porter, 1980) and the Triple Helix Model (Ranga & Etzkowitz, 2015). SWOT Analysis will be used as a tool for the integration of specific characteristics of Mexico.

Porter's Five Forces Model

The Five Forces Industry Analysis was developed by Michael Porter in a 1979 Harvard Business Reviewarticle. Porter's insight revolutionized the strategy field and helped companies asses industry attractiveness, predict how trends will shape industry competition and therefore it is useful for them to know how they can position themselves for success. This framework for understanding the competitive forces at work in an industry, and which drive the way economic value is divided among industry actors. (Porter, 1980) The Five Forces include: the barriers of entrance into the industry, the power of customers, the threat from substitutes, the power of suppliers and the intensity of the competition.

Barriers of entrance refer to how difficult is for others to enter the industry. The power of customers refers to the capacity of customers to bargain and easily more while paying less. The threat from substitutes will depend on the ability of customers to find a different way to satisfy their needs. The power of suppliers refers to the capacity of suppliers to negotiate prices and the intensity of competition is determined by the competitors in the market.

Triple Helix Model

The Triple Helix initiated in the 1990's by Etzkowitz (1993). This model proposes the junction of university-industry-government into a relationship that shapes an industry. It interprets the shift from a dominating industry-government environment (Industrial Society) to a growing triple relationship in which universities are involved to create the Knowledge Society (Ranga & Etzkowitz, 2015). The Triple Helix thesis is that the potential for innovation and economic development in a Knowledge Society relays in the role of universities to generate new institutional and social formats for the production, transfer and application of knowledge.

SWOT

SWOT stands for strengths, weaknesses, opportunities and threats. This analysis can be taken into an organizational or industry level. Strengths and weaknesses are analyzed with an internal criterion while opportunities and threats are based upon the external factors (Harrison, 2010).

Methodology

For the purpose of this research and explanatory industry revision, information was gathered from secondary sources. The main resources where OECD work papers regarding the topic, annual industry reports from the National Institute of Statistics and Geography (INEGI) and most of the background information regarding the national panorama is based on the previous research from Guillermo Foladori apropos Nanotechnologies and their impact in Latin-American Society.

Results & Discussion

The OECD is made up from 34 member countries. In this group, Mexico is considered an emerging economy. Along biotechnology and information technology/communications, nanotechnology is considered a high-tech sector according to the OECD. The support for these sectors, through funding and public policies serve as an indicator of a country's drive for the promotion of competitiveness and development.

R&D activity spending is very low in Mexico. In 2016, it was the 3rd lowest of all OECD countries (0.502% of GDP) (OECD, 2017). While most OECD countries spend an average of around 2% of their GDP of R&D, Mexico's average spending has never gone beyond 0.5%.

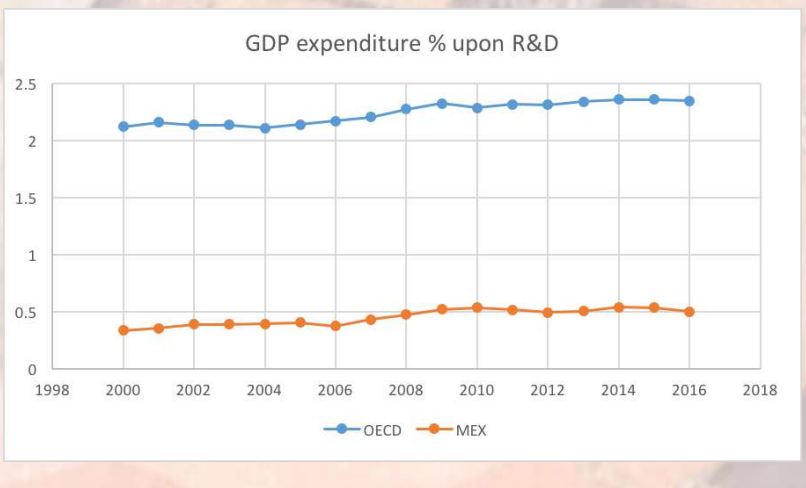

Fig. 1 Gross domestic expenditure on R&D as percentage of GDP – Mexico. Source: OECD 2017.

Another factor that needs to be considered to understand the development of the nanotechnology industry in Mexico is the issue of high mobility of the highly skilled scientific work force. Mexican highly skilled workforce is subject to high mobility (also know as brain drain) as result of globalization (Foladori et. al, 2015).

The development of nanotechnology companies in Mexico is still relatively limited, as reported by Appelbaum et. al, to 2016 there where 139 companies that where involved at a certain point with nanotechnology. The breakdown of these companies and their participation in the supply chain of the industry is the following:

- Produce means of production (96 companies):
  - Nano-materials = 21 companies.
  - Nano-intermediaries = 41 companies.
  - Final products (construction and industry, transport) = 29 companies.
  - Tools and equipment = 5 companies.
- Produce consumer goods (43 companies):
  - Final products (clothing, sporting goods, personal care, food and health) = 43 companies.

As it can be seen, from the 139 companies enrolled in nanotechnology business, 69% contribute to means of production while 31% produce final consumer goods.

Fig. 2 Geographic Distribution of nanotechnology companies in Mexico. Source: (Appelbaum et. al, 2016)

Porter's Five Forces

Threat of New Entrants

The barriers of entrance into the industry are high. This is because there the financial means through which companies can enter is relay high. Even with the financial means being covered, the technical knowledge that is needed to enter into the industry is complex. To counter these barriers of entrance, investment has gone through three main ways (Appelbaum et. al, 2016):

- Specialized Laboratories
- Research Networks
- Industrial Parks

Bargaining Power of Buyers

As the national market is fairly incipient, both buyers and companies are still focused in the R&D phases of several projects. As a complex and highly technical industry, in several cases buyers are the ones that finance and work in synergy with laboratories, universities and industrial parks to develop their products. In this extend, bargain power of buyers is high but it involves high stakes and long-time relationships.

Threat of Substitute Products or Services

The threat for substitute products is fairly low because of the high barriers of entrance into the industry, and also because of the innovation sector in which it develops. High-tech industries are considered as non-saturated and it can be said that in at this point in Mexico the technology adoption life-cycle is still in the innovators and early adopters stage. However, this is just considering the national industry, while U.S., Chinese and European companies have developed first in this sense and might be considered the direct competition of the national market.

Power of Suppliers

As seen in the work of (Appelbaum et. al, 2016), the current nanotechnology companies in Mexico are located in a fair amount in the first stages of the nanotechnology value chain (produce means of production). In this sense, many nanotechnology companies that are begining to involve in nanotechnology currently are at the stage of suppliers, therefore it is redudant to speak of power of suppliers and their leverage.

Rivalry Among Existing Competitors

The stage at which it can be identified the nanotechnology industry in Mexico is at a moment of extensive research. In this extent public research faculties, specialized laboratories and industrial corporations work trying to develop new technologies, materials and products through nanotechnology. This could be considered as a positive competition but the market is far from being considered an economic perfect market and if any company with a significant financial power decides, it would be possible for the company to take a straight leadership in the national market.

Triple Helix Analysis

Universities

The actual state of Mexico's education structure towards Nanotechnology is fairly straight forward. In the country there are 44 doctoral programs, 43 master's program and 12 undergraduate programs in nanotechnology. The 87 graduate programs are distributed across 27 institutions and there are enrolled about 500 students at a graduate level. One of the weaknesses of these education structure is that none of these programs are designed directly by Mexico's Science and Technology National Council, CONACYT (Foladori et. al 2015). In the area of publications, the great majority of publications in Mexico about nanotechnology are the product of researchers affiliated with public institutions. In the Triple Helix model, the universities are the entities in charge of the creation and transfer of knowledge. This purpose is accomplished through an infrastructure made up by research centers, technological institutes and the same universities. The lack of participation of universities in Mexico's Triple Helix can be tracked down to an issue between the national's education system main purpose and the role that universities must assume in the Triple Helix model. The main objective of the academy in Mexico is education (Ponce Jaramillo & Güemes Castorena, 2016), which lacks an innovative vision. The consequence of this approach is the lack of linkage between projects of academia and industry despite the efforts made by the government and industry. In this sense, Mexico's education system should adapt to create a proper approach that enables an innovation objective beyond the mere education purpose.

Government

CONACYT is the governmental entity in charge of the science and technology development of the country. In this sense, is the main mediator between Industry-Government-Universities. The actual panorama is that the Mexican government is attempting to reverse the tendency toward a concentration in scientific and technological capacity across few states. Thanks to CONACYT, state governments have created the "Mixed Fund" program in which blind trusts are assigned to federal organizations to promote research. The main benefited states of this mixed fund program have been Nuevo León, Baja California, Guanajuato, Hidalgo and Veracruz (Záyago, Frederick, & Foladori, 2014).

Industry

In Mexico there is not an institution nor a public program that establish guidelines for the development of nanotechnology, nor comprehensively compile information on nanotechnology. There is some scattered data available but here is no data set that enables to estimate the total investment in nanotechnology. However, as Foladori reported (2016) the survey carried out at the industry level showed that most of the actual nanotechnology industry is primarily divided into the market of final products and the other half are primary nano-materials, intermediary-materials and instruments.

SWOT Analysis

The SWOT Matrix when used as a tool for enterprise environment analysis can provide great insight about the position of an industry or business in relation with other participants of the same business environment. In the case of Nanotechnology Industry in Mexico, the SWOT analysis can be used as a benchmark tool to compare the actual situation in the local scenario with the main countries that lead this industry. Also, it can provide insight about any possible competitive advantages that would make this national industry an attractive business sector private and foreign entities.

Strengths	Opportunities

- Industrial and manufacture environment. - Different programs (public and private funded) to promote nanotechnology. - Education institutions with significant programs. - Presence of several multinational companies of the automobile and aerospace industry.	- Competitive advantage in comparison with other OECD countries. - Research network development to take advantage of earlier nano-industry development. - Multiple Free Trade Agreements position the developing industry in favorable conditions to commerce.
Weaknesses	**Threats**
- Low R&D investment. - Low patent and publication productions. - Interacting problems between universities-government. - High mobility in highly skilled scientific workers.	- Highly specialized Industry. - Financial investment is large and long term orientated. - No present regulation of nanotechnology (Záyago, Frederick, & Foladori, 2014) - More developed external nanotechnology industries.

As it can be seen, some of the competitive advantages that characterize Mexico are regarding its manufacture industry infrastructure. A promising course of action for the public and private Nanotechnology research institutes' initiatives is to direct their work towards the manufacture sector's needs. In this way, the actual state of Mexican economic environment would be used as a platform to develop this cutting-edge technologic industry

Conclusions

Nanotechnologies are changing the world and the way in which industries interact with the market. In this extent, it can be seen that in high-tech and emerging industries such as nanotechnology the need for synergy between universities-government-industry is high and corporations can not underestimate this factors in their industry strategy. The result of Porter's Five Forces Industry Analysis, Triple

Helix Model and SWOT analysis show that Mexico's State of the Art regarding nanotechnology industry differs from the leading countries such as U.S.A, China and European countries in the means that there is limited human and technical infrastructure and low governmental RD investment. However, other characteristics such as the current manufacture environment and their specific interest in Nanotechnology, makes this incipient industry a promising investment for public and private corporations.

Limitations

The limitations of the analysis that was performed are up to the statistical difficulties of the data gathering. INEGI, as a main source, is very limited in the information that it posses regarding nanotechnology and its indicators. A more constant source is the OECD but the data sets tend to vary and there is still a lot of work in terms of datasets to ensure reliable and constant information about nanotechnology, its industry, development and investment.

Recommendations

Further recommendations for next phases of the project are to limit the extension of the research and contact the main authors of the topic in Mexico. Even with a scarce amount of statistical data, to talk about a Nanotechnology Industry as a whole is a huge task to carry out. Also, authors such as Foladori, Appelbaum and Záyago are the main authors of Nanotechnology Industry Development in Mexico to the best of my knowledge. Establishing communication with these authors would provide great insight about the topic.

References

Loeve, S. (2010). About a Definition of Nano: How to Articulate Nano and Technology? *International Journal of Philosophy of Chemistry*(1), 3-18.

Appelbaum, R., Lau, E. Z., Foladori, G., Parker, R., Villa, L., Robles, E., & Arteaga, E. (2016). Inventory of Nanotechnology Companies in Mexico. *Journal of Nanoparticles Research, 18*(43).

Flynn, H. (2014). Nanotechnol.ogy update: corportations up their revenues for nanoenabled products increase.

Fiederichs, S., & Beuzkom, B. v. (2018). *Revised proposal for the revision of the statistical definitions of biotechnology and nanotechnology.* OECD Science, Technology and Industry Working Pepers. Paris: OECD Publishing.

Foladori, G., Figueroa, E. A., Lau, E. Z., Appelbaum, R., Robles-Belmonte, E., Villa, L., Leos, V. (2015). Nanotechnology in Mexico: Key Findings Based on OECD Criteria. *Science+Business*.

Harrison, J. P. (2010). Strategic Planning and SWOT Analysis. In J. P. Harrison, *Essentials of Strategic Planning in Healthcare.* Health Administration Press.

OECD. (2017). *Gross Domestic Spending of R&D.* Paris: OECD Publications.

Ponce Jaramillo, I. E., & Güemes Castorena, D. (n.d.).

Porter, M. (1980). *Competitive Strategy: Techniques for Analyzing Industries and Competitors.* New York: The Free Press.

Ranga, M., & Etzkowitz, H. (2015). Triple Helix System: An Anlytical Framework for Innovation Policy and Practice in the Knowdlege Society. *Entrepreneurship and Knowdlege*.

Záyago, E., Frederick, S., & Foladori, G. (2014). Twelve years of nanoscience and nanotechnology publications in Mexico. *Journal of Nanoparticle Research*.