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Innovation Environments: A Comparison between Mexico and BRICS

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***Abstract*—**To give a general view of the innovation environments is the aim of this paper, we pretend to make an analysis between Mexico and BRICS (Brazil, Russia, India, China and South Africa-countries belonging to the group of five major emerging economies). The comparison takes by reference a set of various indicators that directly or indirectly affect innovation in a positive or negative way. Firstly, a research to obtain the values of each of the indicators was conducted, considering the main primary sources, then, within a set of radial charts is presented the resulting values of each nation and a comparison between them. Finally, a description of the gaps between Mexico and the BRICS were established, including the areas of opportunity for Mexico.

***Keywords*—**Innovation, triple-helix, innovation systems, indicators.

I. Introduction

BRICS is used as an acronym in the international economic community to identify a group of nations considered as emergent economies. These economies are Brazil, Russia, India, China and South Africa. They are distinguished by fast economic growth and for having significant influence in regional or global business and are also members of the G20 or the Group of Twenty.

The countries in the BRICS [1] created a collaboration of supranational credit and developed banks, which have an influence in the world financial system; they have supported the members of the group in different areas of development, including innovation [2].

The Organization for Economic Co-operation and Development (OECD) [3] indicates that the commercial practice in Mexico is focused mainly in the workforce's low costs. Nowadays, the competitive advantage of outstandingly technologically developed countries is determined by their ability to innovate, leaving behind the advantage generated by a low cost workforce.

II. Explanatory Framework

The classic text of Roy Rothwell (1992), titled "Successful industrial innovation: critical factors for the 1990s", was the base to delimit five innovation model generations, it has been accumulating elements using the public politics and the managerial action, to promote the creation of new products, process and services [4].

The first model was denominated "thrust", which is characterized by considering the innovation as a linear project, initiated by scientific findings. Thus, the main aspect of this model to start the research was the inclusion of the private and public investment in basic research, combined with large scale manufacturing. This model was applied during the decades of 1950 and 1960.

The second generation emphasis in the market demand, innovations should be stimulated by identify needs, which "pull" the research and the development. The fundamental aspect of this model would be to know the market and planning, treating and predicting future requirements to satisfy the final user. The model application was dominating until the second half of 1960's decade.

The third generation joins the science push force with the pull power demand, dynamizing a sequential process with a feedback. The fundamental factor of the model would be the communication and the integration of different functional areas to decrease the costs and joining forces.

The fourth generation was applied during the 1970's decade and early 1980's. It stands out in the interactions and the interdependencies between different organizations in many points of the supply chains. The fundamental factor for innovation would be the strategic alliances, access to resources, economic diversification and technology accumulation.

For the fifth generation, valid since the 1990's, what stands out is the network and systems integration, reinforced by automation, communication, information technology (TICs) and the new organizational arrangements.

None of these independent factors determine the success of innovation, but the group of them can contribute to successful innovation (inter firm integration, technology accumulation, product strategies integration- manufacturing, the organizational flexibility and productivity, the performance and the product quality, fast arriving to the market and the general ambient).

These five models also recognize that individual and collective skills are required for innovation to answer the fast environmental changes, allowing a better system use, as well as simulation and co-development.

The innovation systemic models are part of this 5th generation model. A system model is a set elements related between them [5], while the complex systems make a nonlinear selection of these relations [6].

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The adaptive systems change to confront the imposed troubles with concordant environment, for that reason are difficult to study and control: evolving, adding new behaviors and anticipating [7]. The innovation processes actually emerged of the relations between the adaptive complex systems.

The innovation system (IS) offers the possibility to analyze public politics at the national or regional level, emphasizing the governments function in the problems resolution that the market is not motivated to solve [8]. Therefore, this model indicates that the innovative activity comes from the inside of the inter-institutional field to allow the access of different institutions to a sharing of resources, as educational centers, productive infrastructure or human capital.

Johnson and Lundvall (2002) conceived the innovation as an interactive process that would produce results per the relation between different institutions, visualizing an interdisciplinary labor. The relationship between social entities are established considering the characteristics that conformed them [9]. This interdisciplinary labor is integrated by an approaching methodology and people´s responsibility [10].

This perspective is relating a holistic and an integral manner the elements that improve the innovation, as the individual and institutional actors, that interacts of a manner independent and nonlinear, such as knowledge interchange, skills and resources, inside of the delimit spaces by their historical development and the physical or cognitive proximity.

Nevertheless, it is difficult to identify, define and relate variables or relevant factors, as well as identify the relations method to settle activities and use a great funds and resources variety [11], [12].

In the last years, Higher Education Institutions (HEI) are in the process of change to improve and compromise external institutions into the academic field. However, the way of change, as well as the manner of relation with other entities, and the performance achievements with the innovation actors, mainly depends on the global structure of the HEI they belong to [13].

It is relevant to emphasize about the undervaluation of the knowledge creation that emerges in the less developed countries, this situation prevents to give a solution to different problems that show specific characteristics in these contexts. The latent knowledge should be considered to reduce the innovation gap.

Making an analogy with the biological ecosystem, the innovation ecosystem is defined by the complex economic dynamic relations between actors and entities that have the function to make possible the technological development and the innovation [14]. Between its components can be mentioned the material resources as facilities and the equipment, the human resources and institutions. Besides, the economy research and the market research can geographically locate [15] this close resources relation.

Due to the great quantity of related uncertainty with the innovation, the ecosystem should resist the failure of nine of each 10 projects. This forces the ecosystem to balance through the efficient use of resources by recovering and reusing, as well as better understanding of the economy research transit to the market. A healthy ecosystem is maintained by itself, it provides interrelation mechanisms and it also provides intangible interrelation between the actors, entities and resources. All of this depends on the technology type, culture and actors intervening the innovation [15].

The triple helix model emerges as a complex study from an evolutionist neo perspective. The triple helix represents the specialization and codification of the academy functional systems, represented by the High Education Systems (IES), industry and the government, which coevolve and constantly define their limits.

The over position of the three circles are relations between communications of a different nature for the sense interchange and the coded expectation of institutionalized selections. The system operates trans-disciplinary to translate discovery contexts in application contexts and vice versa, without damage the integrity of the underlying projects [16].

At the difference of the Innovation Systems (SI), the Triple Helix does not focus in the geographic analysis units but in technological sectors, such as biotechnology. It can be the most important reference for innovation systems to date. This model allows to consider the specific dynamics emerging between the three sectors at any level, national, regional, among others.

Finally, the complex adaptive systems react face the environment changes and their own components. As a result, its behavior is far to be the optimum. The adaptive complex systems never reach this point. They continue to evolve and show new forms of emergent behavior [7].

It cannot be defined how the innovation systems should be, perhaps it is possible to determine which kind of environment is conducive to increase its development. The national level, the environment conditions is defined in great part for the public politics that design and promote each nation, their economic situation and their tangibles and intangibles capacities, that can be measurement through the next indicators:

A. Competitiveness

The global competitiveness report 2014-2015 realized by the World Economic Forum, measures 12 areas that encompass a set of institutions, public politics and factors which determines the productivity level in a country. While the more competitive an economy is, the greater the possibilities to be fast growing. The index is expressed in a measure between 1, the lowest and, 7, the highest [17].

B. Education

It was taken as an indicator result from the Program for International Students Assessment [18], it measures the knowledge in general areas and skill development in reading, math and sciences, which is acquired by students of around 15 years old; the age when they are close to completing mandatory schooling. The index shows the performance in each country in the student's preparation to confront the knowledge society challenges [19].

India, had taken the PISA test in 2009 and used the results as a reference, this one is the last results generated in this country [20]. For South Africa, a country that does not belong to the

group of countries which utilizes the test, was considered the education sub-index of human capital taken from the World Economic Forum [21].

C. The Ability to Do Business

The index to do business of the World Bank (Doing Business 2015: Going Beyond Efficiency) [22], measures in 10 areas the regulations that impulse or inhibit the economic activities and the intellectual property protection for 189 countries. It is an indicator of what the entrepreneurs have to do to convert their ideas in business, without taking into account aspects such as security and corruption [24].

D. Percentage of Capital Expenditure of GDP in R&D (Research & Development).

As a reference of GDP [23], expressing the monetary value of the production of incomes and end demand services of a country for a whole year, and the Capital Expenditure (CAPEX) in the research and the development, which is the egress in the creative work realized of systematical way to increase the knowledge in country and the use of new applications. To express CAPEX as a percentage of GDP obtains an indicator for investment in basic research applied in the experimental development stage [24].

E. Human Capital

Human capital refers to the skills, capacities and the talent that reside in the persons used with productive purposes to generate profits as a fundamental factor to stability, prosperity and competitiveness of nations. The Human Capital Index 2013 from the World Economic Forum is used as an indicator of the human capital development of 122 countries, which has in consideration the educative dimensions, health, wellness, workforce and employment, the environment, as well as the regulatory framework and the infrastructure, which allows to translate the talent into economic value [20].

F. Intellectual Property

Taking into count that legislative variations exist between the countries, this indicator was built adding the patent requests, industrial designs and utility models, published by the World Intellectual Property Organization [21]. Property records held by residents of each country are taken as a basis, in order to protect the intellectual property in the markets where it will expect to exploit an invention, not necessarily where is generated. In the absence of references to an optimal number or ideal registers, it has been taken into account, the highest amount and the lowest in order to normalize an indicator in the scale of 0 to 10.

G. Quality of Life

The Human Development Index 2014, calculated by the United Nations Development Program [22], is a measurement that gives the possibility of the persons who have access to a long and healthy life, the knowledge which promotes a higher quality of life. Also, this index demonstrates how secure and stable these achievements are between 187 countries.

H. Infrastructure

The information technology and the communications are well known as one of the most important resources to foment innovation and the growth of the economy. In the Global Report of Information Technology 2014, from the World Economic Forum [23], are included in the Network Readiness Index which measures the regulatory framework, the market, the public politic, digital infrastructure and the content, the access and usability, as well as the economic and social impact in 148 countries. The scale is from 1 to 7, the last one being the highest value possible.

I. Economic Complexity

As much as a country accumulates knowledge and productive capacities, the better will be the conditions to produce assets with major added value and major prosperity. The knowledge quantity that a country has, is expressed in the biodiversity of the products it exports and in the fact that it cannot manufacture it in other countries. This measures the Economic Complex Index, calculated by Harvard University, for 128 countries [24].

In the base to the major and minor scores, the index obtained was normalized by each country in a scale from 0 to 10.

III. Metholodogy

The article of Aguilar and collaborators [25], was taken as a base for the indicators selection, which were update with available information in 2015, taking the index with the recent information.

To analyze the data and create the radar graphics, it was necessary to express the values of the different indicators between similar scales from 0 to 10. When the indicator presented a possible minimal or maximum value, the first one was adjusted to 0 and the second to 10, it had calculated the value for each country through the cross multiplication. The CAPEX percentage of GDP in R&D and intellectual property was taken as a maximum value, equal to 10, the inversion percentage highest and the major quantity of registers of intellectual property from the top was calculated through cross multiplication of the value for the rest of the countries. Meanwhile, the human capital indicator, expressed in values from -2 to 2, was used in the slope formula, (x=(y-b)/m), to calculate the values of the scale from 0 to 10.

In the homologation of the result per indicator in this scale of 10, it was calculated the average for comparative between countries in general terms the enabling environment for innovation, assuming that the highest values indicate an ambient with better conditions to innovate. Furthermore, the general comparative, built radar graphics to analyze the position of each nation. To identify the factors that differentiated the innovation ambient between the compared nations realized a variance analysis of each indicator.

IV. Results

Table I [3], [18], [20]-[28] shows the obtained index for each country, and the year to which each index refers in each

country. As can be appreciated, the nation with the highest average is China, which obtained the highest indicator in the intellectual property register.

TABLE I
RESULTS INDICATORS - BRICS + MÉXICO

Indicator	Country						Year
	Brazil	Russia	India	China	South Africa	Mexico	
Competitiveness	6.2	6.24	6.01	6.99	6.21	6.1	2014
Education	4.02	4.81	3.45	5.87	3.5	4.17	2012
Ability to do business	6.2	7.03	5.71	6.63	7.74	7.64	2014
Spend percentage GDP in RD	3	2.7	2	4.6	1.9	1.1	2011
Human Capital	4.9	5	4.3	5.5	4.1	4.9	2013
Intellectual Property	0.48	2.57	0.1	10	0.25	0.24	2013
Quality life	7.4	7.7	5.8	7.1	6.5	7.5	2014
Infrastructure	5.69	6.14	5.5	5.79	5.69	5.56	2014
Economic complex	5.1	5.3	5.1	6.6	4.8	7.3	2012
Average	4.8	5.3	4.2	6.6	4.5	4.9	

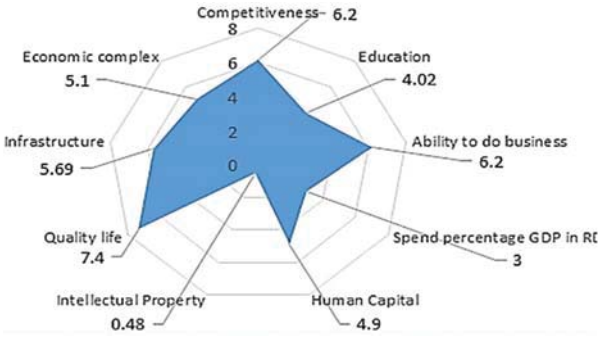

Fig. 1 Brazil

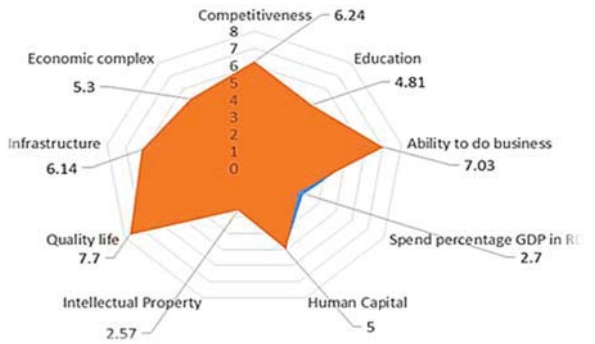

Fig. 2 Russia

In general, Figs. 1-7 have a similar shape. Table II shows the factors that differentiate the performance of innovative nations, they are intellectual property, the percentage GDP expense in R&D, the economic complexity and education, while the rest have a tendency of a similar index, particularly in the infrastructure, competitiveness and human capital.

This indicates the effort that China has been making in the inversion in the R&D and in the Intellectual Property register, where this nation stands out in relation to the rest of the compared countries; furthermore, it is distinguished also in terms of competitiveness, education and human capital.

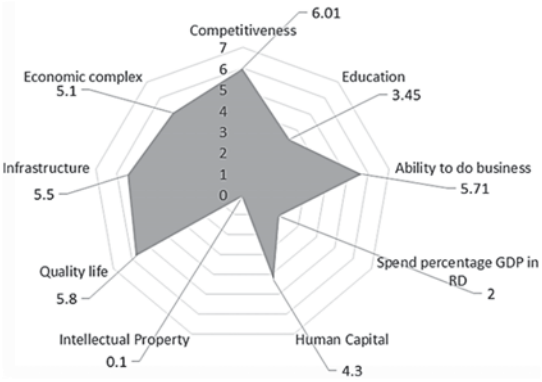

Fig. 3 India

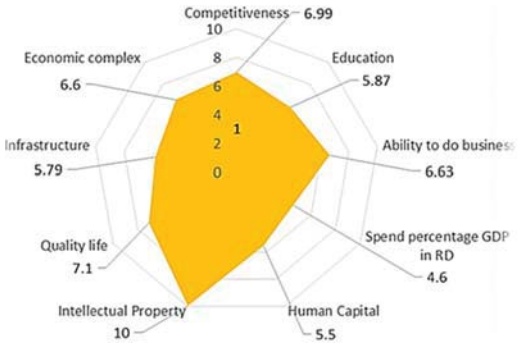

Fig. 4 China

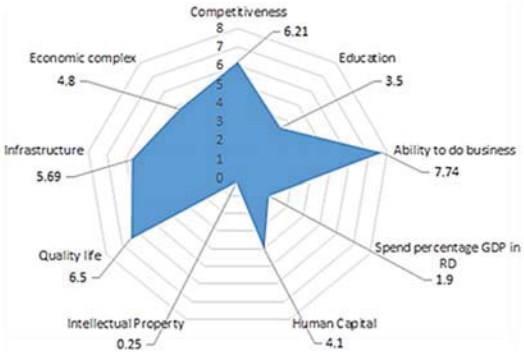

Fig. 5 South Africa

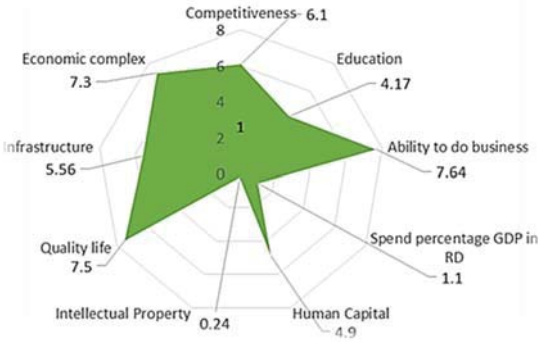

Fig. 6 Mexico

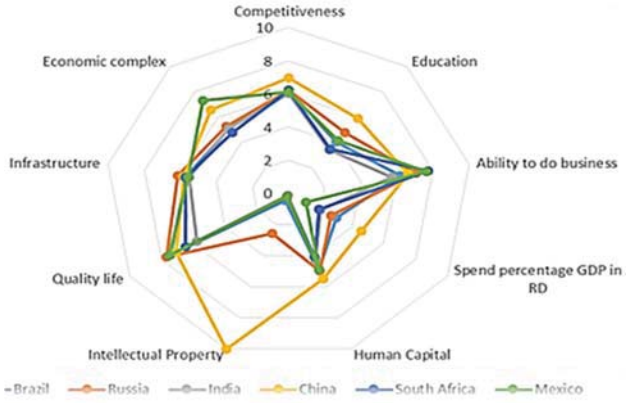

Fig. 7 Comparison between nations

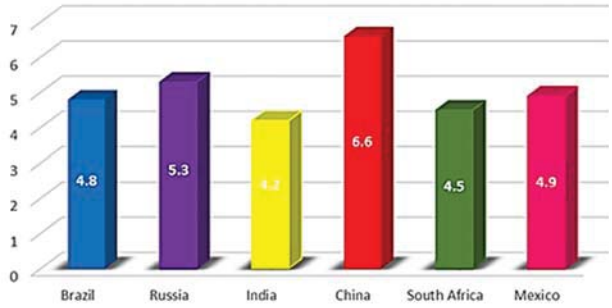

Fig. 8 Comparison between nations in base average obtained

TABLE II
ANALYSIS OF VARIANCE

Indicator	Variance	
		Differentiation
Intellectual Property	12.66	
Spend percentage GDP in RD	1.21	
Economical complexity	0.84	
Education	0.70	
Ability to do business	0.54	
Life quality	0.43	
Human capital	0.21	
Competitiveness	0.10	
Infrastructure	0.04	Standardization

It should be noted that China in the present is a market that is extremely attractive for the commercialization of products and development of services in other parts of the world. Russia, occupies second place and stands out in infrastructure, intellectual property and education, meanwhile; Mexico, in third place, stands out only in the economic complexity, as a differential factor, and in the facility to make businesses and quality of life. There are no fundamental differences with the rest of the compared countries.

V. CONCLUSIONS

It is evident that China is taking the leadership role in innovation among BRICS countries, which allows economic growth to have good possibilities to maintain in the medium and long term. Furthermore, to confirm that an important relative inversion, as well as the intellectual property register, is being affected in a positive way and allows for that nation's consolidation in the global market.

As was mentioned in Sections I-IV, each system is unique in its structure, resources and environment adaptation, and furthermore, are changing constantly, so they cannot set only one ideal system through which can focus the public political efforts. Nevertheless, it is possible indicate to a comparative manner, which factors are marking the difference, in this establishment of an innovative climate between the taken countries taken as part of this study. In this sense, the China climate has the major possibilities to generate different types of organizational arrangements and economics that hold the innovation production that the rest of the countries cannot. Mexico strives to be like China-Innovative.

Mexico has its own possibilities to establish a better climate to innovation, and as shown in the presented data, it is related with the country's economic complexity, which is the factor that was distinguished with more force than the rest of the nations analyzed. As a result of the economic complexity observation, the country exports are identified as raw oil, machinery, including electronic components and products related to transport; this is thanks to the country's location, its inclusion in the TLCAN and its cheap workforce. In these circumstances, it does not seem to have a competitive advantage with great potential in generating added value, indicative of the climate type for which adapting the innovation systems in the country and the possible technological, are the paths that can be taken.

REFERENCES

[1] S A info (2011). New era as South Africa joins BRICS. 20/02/2015, From: SouthAfrica.info Web site: http://www.southafrica.info/global/brics/brics-080411.htm.
[2] Kuzmín, Viktor (2012) 'The BRICS are transformed into an alliance': Russia Beyond the headlines. From: http://es.rbth.com/articles/2012/04/07/los_brics_se_transforman_en_una_alianza_16760.html.
[3] OCDE (2010) Perspectives on Global Development http://www.oecd.org/dev/pgd/perspectivesonglobaldevelopment2010.htm.
[4] Rothwell, R. (1992). 'Successful Industrial Innovation: Critical Factors for the 1990s', *R&D Management*, 22(3): 221–39.
[5] Katz, Daniel and Robert L. Kahn. 1989. *Social psychology of organizations*. México: Trillas.
[6] Luhmann, Niklas. 2007. *Society of Society*. México: Herder / Universidad Iberoamericana.
[7] Holland, John H. 1992. Complex Adaptive Systems. Daedalus, Vol. 121, No. 1, A New Era in Computation (Winter, 1992), pp. 17-30 Published by: The MIT Press on behalf of American Academy of Arts & Sciences. http://research.acer.edu.au/cgi/viewcontent.cgi?article=1000&context=pisa.
[8] Björn, Johnson, Charles Edquist and Bengt-Åke Lundvall. (2003). 'Economic Development and the National System of Innovation Approach', en *First Globelics Conference, Rio de Janeiro*, November 3–6, 2003. (En línea) Disponible: <http://www.globelicsacademy.net/pdf/BengtAkeLundvall_2.pdf>.
[9] Johnson, B. & Lundvall, B-A. (2000): "Promoting Innovation Systems as a Response to the Globalising Learning Economy", presentation for the seminar "Arranjos e Sistemas Produtivos Locais e as Novas Políticas de Desenvolvimento Industrial e Tecnológico", Río de Janeiro.
[10] Bertelsen, P. & Müller, J. (2001): "Who are the ignorant? Current Transformations in Tanzanian Indigenous Technology Systems", Paper for Nordic Africa Days, Uppsala. Edquist, C. (2001). The Systems of Innovation Approach and Innovation Policy: An account of the state of

the art. *National Systems of Innovation, Institutions and Public Policies.* Aalborg.

[11] Edquist, C. (December de 2004). Reflections on the systems of innovation approach. *Science and Public Policy, 31*(6), 485-489.

[12] Marceau, J. (1997): "The Triple Helix: Government-University-Industry Relations in a Small Open Economy", ponencia presentada a la Conferencia Internacional "Las universidades y la economía global del conocimiento: una triple hélice de relaciones universidad-industria-gobierno", Amsterdam, enero.

[13] Sabato, J. & Mackenzie, M. (1982): La producción de tecnología. Autónoma o transnacional, Ed. Nueva Imagen, México.

[14] Jackson, D. J. 2011. What is an innovation ecosystem? *Arlington, VA: National* Science Foundation. Consultado el 20 de febrero de 2015 en: http://www.urenio.org/wp-content/uploads/2011/05/What-is-an-Innovation-Ecosystem.pdf.

[15] Leydesdorff, Loet. 2011. The Triple Helix, Quadruple Helix, and an N-Tuple of Helices: Explanatory Models for Analyzing the Knowledge-Based Economy? Journal of the Knowledge Economy. Volume 3, Issue 1. Pp 25-35.

[16] Leydesdorff, Loet. 2012. The Triple Helix of University-Industry-Government Relations (February 2012). Forthcoming in: Elias Carayannis and David Campbell (Eds.), Encyclopedia of Creativity, Innovation, and Entrepreneurship, New York: Springer. Available at: http://ssrn.com/abstract=1996760.

[17] Schwab, Klaus (Editor). 2014. The Global Competitiveness Report 2014–2015. World Economic Forum. Consultado el 4 de febrero de 2014 en: http://www.weforum.org/reports/global-competitiveness-report-2014-2015.

[18] OECD. 2014. PISA 2012 Technical Report, PISA, OECD Publishing. http://www.oecd.org/pisa/pisaproducts/PISA-2012-technical-report-final.pdf.

[19] Walker, Maurice (2011). 'PISA 2009 Plus Results: Performance of 15-year-olds in reading, mathematics and science for 10 additional participants'. Melbourne: ACER Press.

[20] World Economic Forum. 2013. The Human Capital Report. In collaboration with Mercer and Harvard University. http://www3.weforum.org/docs/WEF_HumanCapitalReport_2013.pdf.

[21] World Bank. 2014. Doing Business 2015: Going Beyond Efficiency. Washington, DC: World Bank. DOI: 10.1596/978-1-4648-0351-2. License: Creative Commons Attribution CC BY 3.0 IGO. http://www.doingbusiness.org/~/media/GIAWB/Doing%20Business/Documents/Annual-Reports/English/DB15-Full-Report.pdf.

[22] World Bank. 2015. Research and development expenditure (% of GDP). http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS/countries/1W-MX?display=default.

[23] United Nations Development Programme. 2014. Human Development Report 2014, Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience. Disponible en: http://hdr.undp.org/sites/default/files/hdr14-report-en-1.pdf.

[24] Hausmann, Ricardo, César A. Hidalgo, Sebastián Bustos, Michele Coscia Sarah Chung, Juan Jimenez, Alexander Simoes, Muhammed A. Yıldırım. 2011. The Atlas of Economic Complexity, Mapping Paths to Prosperity. Harvard University and Massachusetts Institute of Technology. Consultado del 20 de febrero de 2015 en: http://atlas.media.mit.edu/static/atlas/pdf/AtlasOfEconomicComplexity.pdf. Los datos actualizados a 2012 están disponibles en: http://atlas.cid.harvard.edu/rankings/country/2012/.

[25] Aguilar Peña Juan M., Valencia Luis, Pastrana Alberto, Nava Estefany, Martínez A., Vivanco M., Castañeda A. (2014). "Radar Charts Analysis to Compare the Level of Innovation in Mexico with Most Innovative Countries in Triple Helix Schema Economic and Human Factor Dimension". *World Academy of Science, Engineering and Technology International Journal of Social, Management, Economics and Business Engineering*. Vol:8 No:4. Pp 945 – 951.

[26] World Economic Forum. 2014. The Global Information Technology Report 2014, Rewards and Risks of Big Data. Consultado el 20 de febrero de 2014 en: http://www3.weforum.org/docs/WEF_GlobalInformationTechnology_Report_2014.pdf.

[27] World Intellectual Property Organization. 2014. World Intellectual Property Indicators. Consultado el 09 de febrero de 2014 en: http://www.wipo.int/ipstats/en/wipi/.

[28] World Economic Forum. 2014. The Global Information Technology Report 2014, Rewards and Risks of Big Data. Consultado el 20 de febrero de 2014 en: http://www3.weforum.org/docs/WEF_GlobalInformationTechnology_Report_2014.pdf.

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