Global Journal of Business Research
Vol. 8, No. 5, 2014, pp. 73-83
ISSN: 1931-0277 (print)
ISSN: 2157-0191 (online)

www.theIBFR.org

COUNTRIES' COMPETITIVENESS ON INNOVATION AND TECHNOLOGY

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ABSTRACT

Innovation and technology are main sources of competitiveness. This study addresses two research questions. First, which economies are competitive in terms of innovation and technology? Second, what are the variables that determine competitiveness in innovation and technology? Analysis of Factorial of Correspondences (AFC), through the analysis of principal components methodology, is employed in this article. The analysis is divided into five phases as follows: a) reliability testing, b) the calculation of a matrix that expresses the joint variability of the variables, c) extraction of the optimal number of factors, d) the rotation of solutions for the ease of interpretation, e) estimation of the scores graphically, and f) determination of the competitiveness index.

JEL: O31, O32

KEYWORDS: Innovation, Technology, Competitiveness, AFC, Multivariate Analysis

INTRODUCTION

Innovation and technology are key components that define competitiveness strategy. Competitive forces such as intense global competition, fragmented and demanding markets, and diverse and rapidly changing technologies make it vital to define public policies centered on knowledge and to transform them for the well-being of society.

Evidence shows a strong contribution of young firms that implement innovation and technology to job creation (OECD, 2013). In modern times, innovation and implamentation of technology is crucial for governments and firms to compete in the domestic and international framework. Today, knowledge in all its forms plays a crucial role in economic processes. Nations which develop and manage effectively their knowledge assets perform better. Firms with more knowledge systematically outperform those with less. Individuals with more knowledge get better paid jobs. This strategic role of knowledge underlies increasing investments in research and development, education and training, and other intangible investments, which have grown more rapidly than physical investment in most countries and for most of the last decades. Policy framework should thus put central emphasis on innovation and knowledge-creation using the capacity of OECD economies. Technological change results from innovative activities, including investments such as R&D, and creates opportunities for further investment in productive capacity. In the long term, it creates jobs and more income. A main task for governments is to create conditions that induce firms to engage in the investments and innovative activities required for enhancing technical change" (Jaramillo *et al,* 2005).

At the macro-level, there is a substantial body of evidence that innovation is the dominant factor in national economic growth and international patterns of trade. At the micro-level, within firms, R&D enhances a firm's capacity to absorb and make use of new knowledge of all kinds, not just technological knowledge.

The aim of this work is to measure the impact of different variables that affect innovation and technology, as well as the real economy. The overall goal of this research is to obtain an index for competitiveness of innovation and technology. Specifically, we study the economies of thirty-four countries, taking as a parameter the study international trade flow according to the Bank of International Settlements (2007). The economies considered were: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Cyprus, Korea, Estonia, Finland, France, Germany, Greece, Hong Kong, Ireland, Italy, Japan, Luxembourg, Malta, Mexico, Netherlands, Norway, Portugal, Singapore, Slovakia, Slovenia, Spain, Switzerland, Sweden, United Kingdom, United States, and the Euro-zone.

The hypothesis for this work is that competitiveness of countries in innovation and technology is determined by high technology development and innovation; global investment in innovation and development; percentage positioning of investment and development in technology and innovation; and complementary indicators of technological development. Thirteen indicators were considered in the study: Exports of products of high technology (in dollars to current prices); exports of products of high technology like percentage of exports of manufacture; requests of patents of non-residents; requests of residents' patents; expense in research and development as percentage of the Gross Domestic Product (GDP); researchers dedicated to innovation and development (million persons); payments for copyright and licenses; articles in scientific and technological publications; specialists, technical personnel, in innovation and development; trademark applications by non-residents; trademark applications from residents; conclusion of college education as a percentage of education; and researchers as a percentage of population. These indicators were collected from the World Bank and International Monetary Fund data base for the year 2010.

The paper is organized as follows. In section two we present the literature reviewed. Section three presents the methodology used and selection of the data. Section four shows the principal results of the competitiveness analysis with the help of the Principal Component Analysis and section five provides concluding remarks.

LITERATURE REVIEW

In 1912 Schumpeter introduced the creative destruction concept as a process to grow through products, process and organizational activities innovation. The economy and society change when factors of production are combined in a novel way. Schumpeter suggests that invention and innovation are key to economic growth and those implementing the change are practically entrepreneurs. Penrose (1959) provides an explanatory logic that clarifies the causal links between resources, capabilities, and competitive advantage, thereby contributing further to the development of a theory of the firm based on resources, known as Resource-based View competitive advantage.

Nelson & Winter (1982), suggest that resources of the company are not only physical and human, but an important dimension is organizational routines. These routines are understood as required administrative mechanisms for the transformation of inputs into outputs. Company efficiency is a function of routines, which are the product of accumulated organizational history (path dependence). Disseminated throughout the company, these routines are not incorporated individually. In the perspective of the Resources Based View, mention of management strategies for capacity development (Wernerfelt, 1984) is made. Certainly, if the control of scarce resources by firms is the source of economic gains, then problems such as the acquisition of skills, knowledge and management know-how, and learning become central problems.

In recent years this dimension of skill acquisition, learning and accumulation of intangible assets has attracted interest from many disciplines of study. The theory of capabilities arises precisely to try to address these concerns in an environment where it is observed that companies considered winners in a global market are those that demonstrate responsiveness (timing), and an innovation fast and flexible product development, coupled with capabilities of managers to coordinate and effectively redistribute internal and external powers. This ability to acquire new competitive advantages is called dynamic capabilities. To achieve dynamic capabilities it is necessary to continuously monitor markets and technologies, and have a willingness to constantly adopt best practices (Teece, et al., 1997).

There have been several theoretical studies and cross-empirical analyzes have focused their analysis on specific aspects of the sectors. Industrial economy studies have examined differences in concentration; vertical integration; entry; industrial; or strategic behavior dynamics and interactions between companies and have been linked to some underlying differences in technology; demand; entry barriers or other related sectorial context variables. Studies in the evolutionary tradition have focused on differences in knowledge, learning and innovation across sectors. Sectorial differences are related to the technological environment and knowledge as well as the accumulation of skills by companies. Similarly, the literature on innovation systems and technology has emphasized innovation processes in the interaction between agents and the role of non-business organization and institutions across sectors and technologies (Malerba, 1999).

There are several studies that frame the effects of innovation and technology impact in the economy as a factor of competitiveness. These works include the Innovation Union Scoreboard (2013). The Scoreboard gives a comparative assessment of the innovation performance of the EU27 Member States and relative strengths and weakness of research and innovation systems using 3 types of indicators (enablers, firm activities and outputs) and 8 innovation dimensions (human resources, open, excellent, attractive research systems, finance and support, firm investments linkages & entrepreneurship, intellectual assets, innovators and economic effects) capturing in total 25 different indicators. The main results of the grouping analysis show that most European countries have regions at different levels of performance. In France and Portugal at least one region falls in each of the 4 broader performance groups. Czech Republic, Finland, Italy, Netherlands, Norway, Spain, Sweden and the UK have at least one region in 3 different performance groups. This regional diversity in innovation performance also calls for regional innovation support programmers better tailored to meet the needs of individual regions.

The Oslo Manual is an obligatory step in the discussion of innovation and technology. It concentrates on two Schumpeter's categories, new and improved products and processes. The minimum entry set is "new to the firm" dealing with innovation at the level of the firm. This considers issues such as engaging in a complex set of activities with multiple outcomes, some of which, moreover, can reshape the boundaries and nature of the firm itself.

In 2001 the Bogota Manual was released. This Manual was elaborated by the Red Iberoamericana de Indicadores de Ciencia y Tecnología (RICYT) , the Organización de Estados Americanos (OEA) and the PROGRAMA CYTED. This manual was designed for a better understanding of the technological and innovation development of Latin America and the Caribbean. The manual accomplished this main goal considering fundamental aspects: a) the capture indicators consider the specificity of the technological innovation process in the region and b) the synthetic indicators allow the comparative analysis at an international level.

The Mexican Consultation Group of the FOBESII is another interesting study created to analyze the current educational, academic and scientific linkages between Mexico and the U.S., as well as to make recommendations to promote greater interaction. This Group is formed by Mexican experts from 35 institutions from the academic, public, private and social sectors. The research is divided into eight working groups: Relevance, Undergraduate Mobility, Graduate Studies, Academic Exchange, Technological Development and Innovation, Internships, Languages, and Promotion.

There are several indexes that seek to measure the degree of competitiveness of economies among them are: the global competitiveness index by country WEF 2012-2013, index WEF Global Competitiveness: Innovation 2008-2013, index of international competitiveness of IMCO, index IMD's competitiveness, among others.

Although these indices have a pillar or dimension that seeks to measure the innovation and technology degree, they are not entirely focused on the measurement of these variables. Therefore an index to measure not only the countries innovation and technology degree but also links these variables to the international trade flow performance of countries, can be very interesting. This allows for adding new elements to create strategies for the wellbeing of society and bringing new elements to the state of the art in technology and innovation advancement.

METHODOLOGY

Factorial Analysis is a multivariate statistical technique, which is the underlying structure in a data matrix. Factorial analysis allows us to solve the problem of analyzing the structure of interrelationships (correlations) present in a large number of variables and cases, defining a common number of underlying dimensions called components (Guillermo et al., 2010).

Due to the hypothesis consisting of four variables accounting for thirteen indicators, it is necessary to apply a method to see the dependency between each of the indicators. It is also necessary to observe the weight of each variable regarding the problem to be addressed. An ideal tool for this analysis is the Correspondences Factorial Analysis. An analysis of attraction-repulsion among types of different attributes (indicators) allows studies of proximity (similarity/dissimilarity) between the modalities of a single indicator; i.e. it allows the evaluations of homogeneity or substitution thereof (Miquel et al., 1997). For this, the projection of the modalities is presented on a metric space which applies the Analysis of Principal Components to aid in the simple causal interpretation of similarity-attraction behaviors (Kim & Mueller, 1978).

The selected indicators were taken from the statistical data World Bank for the year 2012. The indicators had to go through some filters such as the table of communalities and scree plot, as detailed later. Once the variable pass the test it can be included in the research, so that the variables are: high technology products export (US$), high technology products export (% of exp. of manufacture), Patent applications, non-residents, Patent applications, resident, Spending on R & D (% of the GDP), Researchers R & D (million people), Royalty payments, copyright and license, Scientific and technological publications, MR applications, non-residents, MR applications, residents, Conclusion of educ. top level. (% population) and Researchers (% population).

RESULTS

The Communalities shown in Table 1 indicate the degree of extraction that the study represents for each indicator or the proportion of the variance explained by factorial analysis (Perez, 2006). The principal components method assumes that one hundred per cent of the variance can be observed, so that all indicators are based on the extraction level of one (Kim & Mueller, 1978). It is important to note that if the indicator does not have a score above 0.500 it cannot be considered in the study because the indicator will not be representative for the analysis. In the study, herein, all the indicators are well represented. The indicator with the highest level of extraction was exports of products of high technology with a value of 0.883, followed by requests of residents' registered trademarks and requests of patents of non residents with 0.875 and 0.854 respectively (see Table 1).

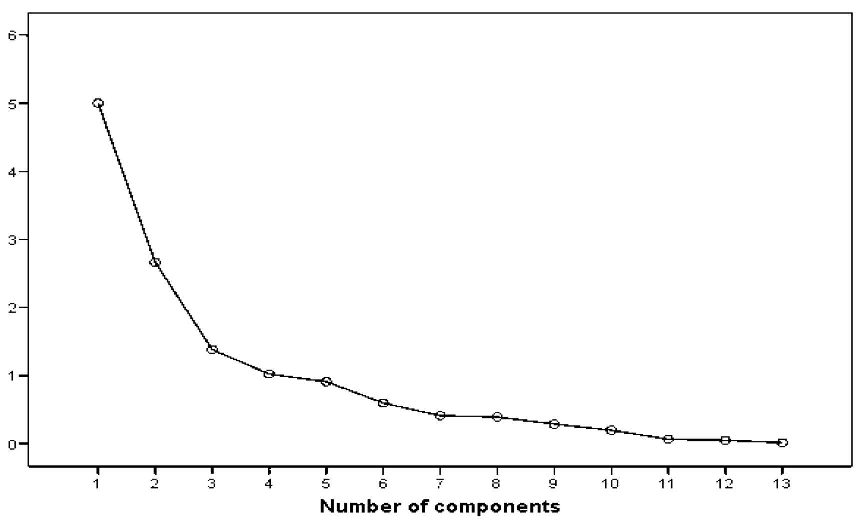
Table 1: Table of Communalities

Indicators	Initial	Extraction
Exports of prod. high technology (US$)	1.000	0.**883**
Exports of prod. high technology (% of exp. of manufacture)	1.000	0.827
Patent applications, non residents	1.000	**0.854**
Patent applications, resident	1.000	0.757
Spending on R & D (Research & Development) (% of the GDP)	1.000	0.831
Researchers R & D (million people)	1.000	0.840
Royalty payments, copyright and license	1.000	0.529
Scientific and technological publications.	1.000	0.755
Specialists in R & D (per million people)	1.000	0.812
MR applications, non residents	1.000	0.782
MR applications, residents	1.000	**0.875**
Conclusion of educ. top level. (% pobl.)	1.000	0.730
Researchers (% population)	1.000	0.797

This table shows the grade of extraction of indicators in order to determine if they are representative for the problem addressed. Method of extraction: Analysis of principal components. Source: Authors' calculations based on the results of the Factorial Analysis of Correspondences.

The scree plot shown in the graph illustrates the percentage of the variance represented by each factor or dimension (Kruskal, 1981), as well as the overall contained degree of reliability. A total of 77.50 percent of variance is represented. The first component shows 38.48 percent, the second component 20.50 percent, the third factor 10.63, and the fourth 7.87 percent (Figure 1).

Figure 1: Scree Plot



Source: Authors' calculations based on the results of the Analysis Factorial of Correspondences.

The Rotated Components Matrix solution, presented in Table 2, shows each of the indicators fall into a single component. The heavy components scores show the space on which the variables are positioned as the relation between the variables and their correlation (for those reproduced in the same component). In the first component, the indicators better represented are exports of products of high technology, patent applications residents and non residents, articles in scientific and technological publications, and trademark applications-residents and non residents. The second set of components are spending on research and development (R & D), R & D researchers, and the top level of education in percentage of the population. The third set of components deal with the exports of products of high technology, such as the percentage of exports of manufacture and researchers as percentage of the population. Finally, the fourth factor involves royalty payments, copyrights and licenses, and technical specialists in R & D.

Table 2: Rotated Components Matrix

Indicators	Components			
	1	2	3	4
Exports of prod. high technology (US$)	**0.884**	0.050	0.283	0.133
Exports of prod. high technology (% of exp. of manufacture)	0.106	0.049	**0.901**	-0.042
Patent applications, non residents	**0.857**	0.306	0.072	-0.144
Patent applications, resident	**0.802**	0.314	0.126	0.001
Spending on R & D (% of the GDP)	0.192	**0.853**	0.188	0.177
Researchers R & D (million people)	- 0.036	**0.885**	0.128	0.197
Royalty payments, copyright and license	0.256	0.173	0.333	**0.451**
Art. in scientific and technological publications.	**0.794**	0.346	0.000	-0.073
Specialists in R & D (per million people)	-0.172	0.111	-0.107	**0.871**
MR applications, non residents	**0.801**	-0.212	0.057	-0.303
MR applications, residents	**0.908**	-0.195	0.110	-0.007
Conclusion of educ. top level. (% pop.)	0.119	**0.821**	-0.190	-0.072
Researchers (% population)	-0.201	0.058	-0.**651**	0.574

This table shows in which component the variables can be better represented in the Extraction Method: Principal Components Analysis. 4 components extracted. Varimax with Kaiser Normalization. The rotation converged in 6 iterations. Source: Authors' calculations based on the results of the Analysis Factorial of Correspondences.

According to the first results obtained, variables are grouped based on components most associated with each other and their degree of the variance. The degree of variance is such (77.48) that the indicators can be integrated into four dimensions. The first factor contains variables related to technology and innovation development. These are represented by a 38.48 percent of the variance. The second factor gathers variables that show global investment in R & D with 20.50 percent. The third factor explains, with a variance of 10.63 percent, the positioning of investment and development in technology and innovation. The fourth factor concerns variables that relate to complementary indicators of technological development with 7.87 per cent of the variance (see Table 3).

Table 3: Proportion of Variance Explained by Each Factor

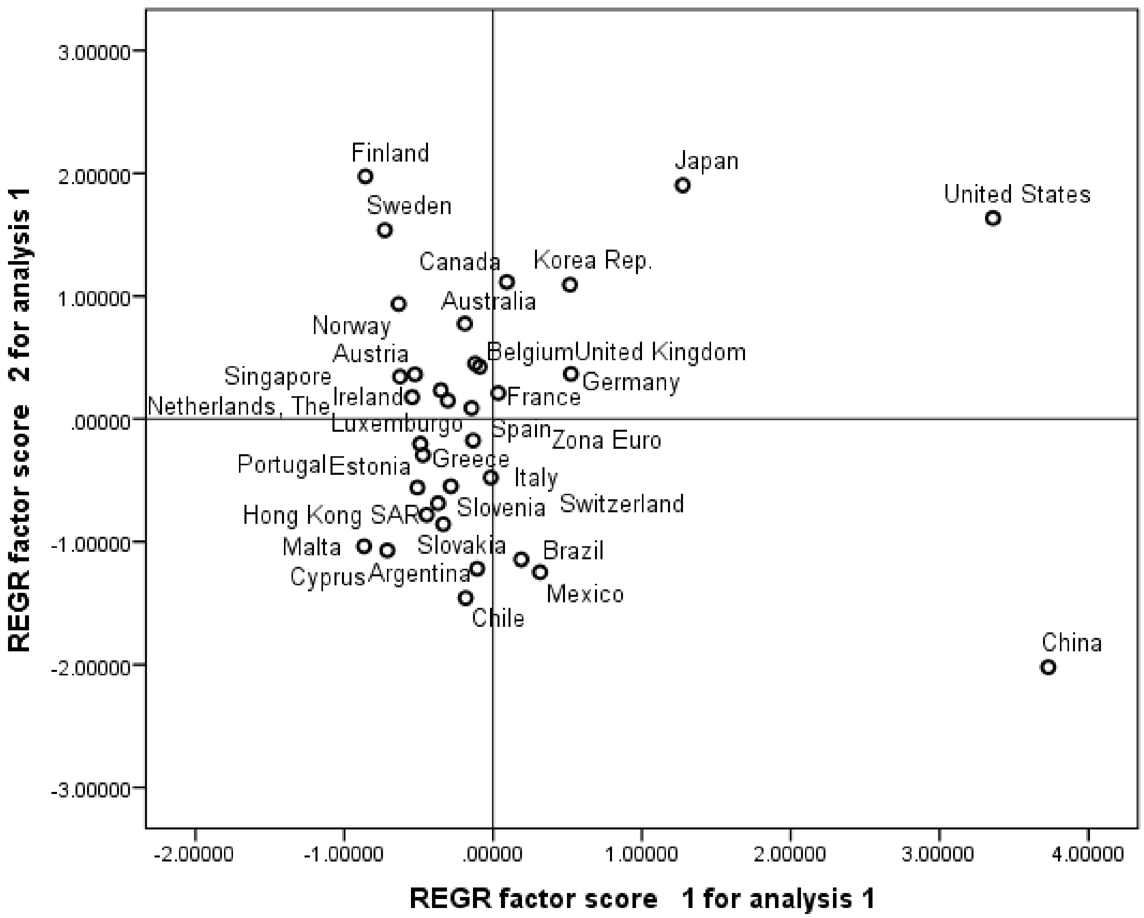
Factor	Sub-Dimension	Proportion Variance Explained
Factor 1	High development on technology and innovation	38.48 %
Factor 2	Global investment in R & D	20.50 %
Factor 3	Percentage positioning of the investment and development in technology and innovation	10.63 %
Factor 4	Complementary indicators of the technological development	7.87 %

This table shows the variance explained by each factor. Source: Author based on the results of the Analysis Factorial of Correspondences.

Chord to the positioning of indicators within the multidimensional space of the X-axis represents the degree of current development in technology and innovation of each economy. This process groups the variable exports of products of high technology to current prices, patent applications of residents and non residents, articles in scientific and technological publications, and trademark applications of residents and non residents. Because the scores are positive (in the rotated components matrix) among the right, most countries will be better positioned. The best placed countries in respect of this axis are China, The United States, Japan, Germany, France, Korea, Switzerland, Mexico, Brazil and Australia while the worst positioned are Cyprus, Finland, Slovakia, Sweden, Portugal, and Estonia.

The Y axis represents the level of global investment in R & D. This is due to variables such as spending on R & D as percentage of the GDP, researchers dedicated to R & D (a million people), and the top educational levels as percentage of the education are incorporated in this sub-dimension. As in factors of the X-axis, the further up economies are located the better located they will be, such as is the case of Finland, Japan, The United States, Sweden, Canada, Korea, Norway, Australia, United Kingdom, Ireland, Germany, France, Belgium, Singapore, Luxembourg, and Spain, in this order. In contrast, Chile, Argentina, Mexico, Cyprus, Brazil, Slovakia and Malta are located further down (see Figure 2).

Figure 2: scores plot factors 1 and 2

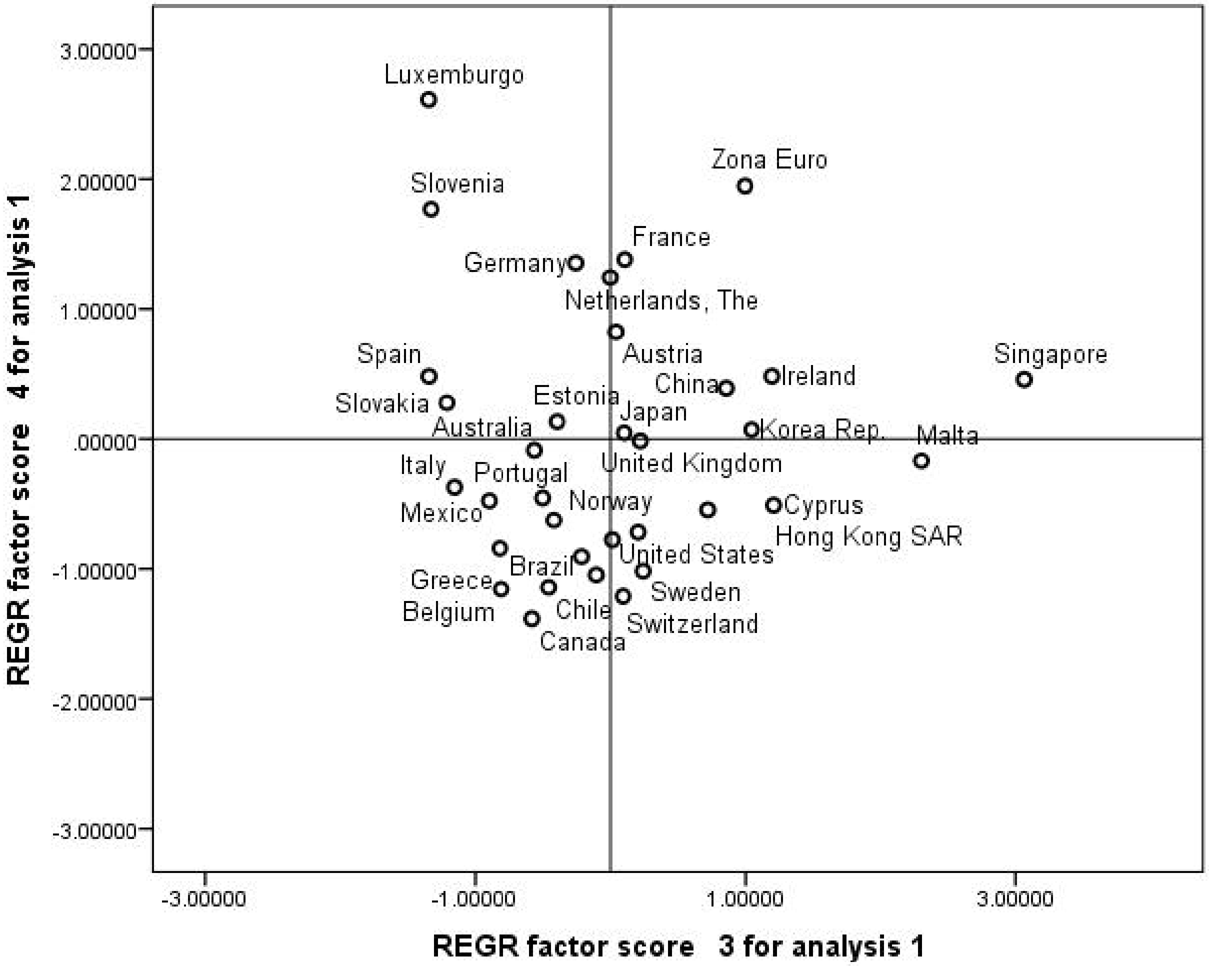


Source: Authors' calculations based on the results of Factorial Analysis of Correspondences.

Figure 3 represents in the X-axis (Component 3) showing the percentage positioning of investment and development in technology and innovation. It contemplates the exports of high-technology products like the percentage of manufacture exports and the number of researchers as a percentage of the population. The complementary indicators of technological development are located on the Y-axis (Component 4). These are royalty payments for copyright and licenses and technical specialists in innovation and development.

Because component 3 has negative and positive values, the best placed countries with respect to the X-axis will be those that tend to zero, such as Japan, United Kingdom, United States, Netherlands, Austria, Sweden, and France. The top-ranked countries respect of the Y-axis will be those who are located at the top of this axis, such as Luxembourg, the Euro-zone, Slovenia, France, Germany, Netherlands, Austria, Singapore, Ireland, China, and Spain (see Figure 3).

Figure 3: Scores Plot Factors 3 and 4



Source: Authors' calculations based on the results of the Factorial Analysis of Correspondences.

The competitiveness index obtained accounts for the position of each country analyzed to combine the results for each of the dimensions. The index reveals the countries that have better ranking or are more competitive in innovation and technology. The economy with the highest index of competitiveness is the United States followed in descending order by China, Japan, Korea, Germany, Singapore, France, the Euro-zone, Canada and United Kingdom. The minor indexes find Chile, Slovakia, Cyprus, Greece, Argentina, Sweden, Estonia, Portugal, Malta, Hong Kong, and Mexico with the sample mean of 2.6 (Table 4).

CONCLUDING COMMENTS

We examine the hypothesis: competitiveness of countries on innovation and technology is determined by high technology development and innovation, global investment in innovation and development, percentage positioning of investment and development in technology and innovation, and the complementary indicators of technological development. The results show high technology development and innovation and global investment in innovation and development have greater weight in determining the innovation and technology competitiveness. The aim of this work is to measure the impact of different variables that affect innovation and technology, as well as the real economy. The overall goal of this research was accomplish.

Table 4: Competitiveness Index Dimension of Technology

País Dimensión	INNOVACIÓN Y TECNOLOGÍA	País Dimensión	INNOVACIÓN Y TECNOLOGÍA
United States	9.01	Spain	2.39
China	7.36	Norway	2.38
Japan	6.40	Brazil	1.95
Germany	4.32	Italy	1.95
Singapore	3.69	Mexico	1.91
France	3.62	Portugal	1.71
Zona Euro	3.60	Estonia	1.62
Canada	3.30	Switzerland	1.51
United Kingdom	3.23	Argentina	1.45
Finland	3.10	Greece	1.41
Australia	3.02	Slovakia	1.35
Netherlands, The	2.98	Chile	0.97
Ireland	2.91		
Sweden	2.87	SUM	88.0
Luxemburgo	2.84	MEDIA	2.65142829
Austria	2.71	AVARAGE	3.0
Belgium	2.43		

Source: Authors' calculations based on the results of the Factorial Analysis of Correspondences.

By integrating the results of components one and two that explain the degree of development in technology and innovation (X-axis) and the investment in research and development (Y-axis), it is observed that the top-ranked countries are located in the first quadrant, i.e., The United States, Japan, Korea, Germany, France, and United Kingdom. Whereas the countries worse placed are Cyprus, Malta, Argentina, and Chile.

The United States is best placed in terms of development in technology and innovation and in investment in research and development. China, according to the results of the study, has a high degree of development in technology and innovation but a low degree of investment in research and development
Among the best positioned economies in an international context, according to the index of competitiveness of innovation and technology, are the United States followed (consecutively) by China, Japan, Korea, Germany, Singapore, France, and the Euro-zone.

Mexico appears at position number 13 in terms of competitiveness in innovation and technology with 1.91 points, which places it below the average (2.93). It is important to point out that indicators which place Mexico at a lower level are the number of researchers in R & D, articles in scientific and technological publications, and patent applications of residents, where Mexico shows a value far below of the average.

Developed countries seek to support links between the development of educational and scientific systems with the ability to innovate in the real sector of their economies. This is still not on the agenda of many developing countries such as Mexico. This study identified elements that can lead to strategies aimed at the promotion of innovation and technological development, emphasizing strategies directed to the formation of researcher-driven innovation and technology, promotion of publications and creation of magazines related to science and technology; strategies that link the academic and business sectors, as well as the use of patents generated in order to boost competitiveness and development in Mexico.

Among some limitations on this paper are the number of units of analysis. Future research could be done grouping countries by continent or GDP. Another limitation of the study is the time frame because the data is limited to the year 2012.

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