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The regional network capital index in Mexico from 2012 to 2016

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ABSTRACT

Based-off the regional development theory developed from knowledge and innovation, Huggins & Thompson [1] have proposed the concept of Network Capital, which aims to explain the importance of knowledge flow, knowledge absorptive capacity and investments on associations between firms and Universities or Scientific Centers or other firms in order to increase regional development. This paper used empirical data from Mexico for the period 2012–2016 to propose an alternative to the calculation of Network Capital at State level as an alternative to the Huggins and Thompson proposal. The data used cover all the 32 Mexican States about innovation activities. On this paper is shown the deep differences between Mexican States about the knowledge qualities, the absorptive capacity of knowledge and the investments on strategic associations, it that might be typical at non-innovation Nations. Although the proposal on this paper cannot be directly compared to that of Huggins and Thompson, both shows evidence that, the greater network capital, the greater the potential development based on knowledge.

1. Introduction

There is a growing consensus that at the regional level, the innovation process requires the existence of inter-organizational networks that facilitate the flow of knowledge that is not or cannot be generated internally in the organization [2,3]; so, some authors has been research how the structure and function of a network or the geographic coverage influences their capacity for aggregate innovation [4–7].

Huggins & Thompson [8] describe these networks as channels in which the flow of knowledge can improve the ability of companies to obtain higher returns and Huggins [9], states that this ability is a form of capital, which he defines using the concept of network capital, this concept could be associated with the process of regional innovation, which it is widely accepted as contributing to regional growth, and can therefore be an important element to consider within regional growth models.

According to the authors [1,5], the value of network capital can be determined by considering three elements: (a) the characteristics or qualities of the knowledge that flows between organizations (superiority, exclusivity and ability to mix with other knowledge); (b) the knowledge absorptive capacity of organizations; and (c) the value of those knowledge relations or links that are strategically established in the search for greater profitability.

The concept of network capital allows an in-depth academic study of the dynamics of regional growth, since it exposes a characterization of the flow of knowledge, which is a different perspective from the traditional methods of measuring innovation that use accounting indicators such as the number of patents, scientific articles, and new companies, among others.

The theoretical [5] and empirical [10] analyses indicate that there is a positive correlation between a high level of network capital and high economic growth in the regions where these inter-organizational relationships occur, however, the data they used in their studies is endemic to the UK regions, making it difficult to replicate to other regions of the world.

This paper presents an empirical alternative to data and approach to the one used by Huggins and Thompson to measure the regional network capital, for this purpose, empirical data are used to capture at regional level and separately the three elements associated with network capital. Additionally, a regional Network Capital Index is directly constructed instead of being calculated as an aggregate of firm-level values as they do [10]. With these modifications, the concept of network capital could be used in different regions and/or countries that do not have information on the level used by Huggins and Thompson, but instead could

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use locally available indicators that better capture the three concepts.

The empirical data comes from the 32 States or Federal Entities that make up the Mexican Republic, and although each State has different economic development, in general the northern and central States are the most developed. The Mexican Republic has almost 125 million inhabitants with an economically active population of approximately 57 million and in international rankings it is in 55th place in the Global Innovation Index 2020, in 48th place in the Global Competitive Report 2019 and has 4.7 points in the National Entrepreneurship Context Index 2020 (NECI) of the Global Entrepreneurship Monitor.

The data used in this research comes from various sources with public data such as the Innovation Stimulus Program (PEI) of the National Council for Science and Technology (CONACYT), the Ministry of Economy (SE), the National Association of Universities and Higher Education Institutions (ANUIES), the Ministry of Labor and Social Welfare (STPS), the National Institute of Statistics, Geography and Informatics (INEGI) among others official databases; also, the present proposal makes use of dichotomous variables to incorporate the qualitative variables and the Principal Component Analysis (PCA) technique to determine the relevance of the variables used; the methodology shown consists in assessing the three key elements of the concept of network capital: (a) the regional knowledge qualities, (b) the regional absorptive capacity of the knowledge and (c) the regional value of the strategic network connections.

The remainder of the paper is structured as follows: section 2 sets out the theoretical proposal of the authors of the concept to value network capital and based on this describes the empirical alternative to data and approach to the one used by Huggins and Thompson; the arguments and sources of information used for the case of Mexico's regions are also presented, and a performance index is obtained for each element of network capital. Section 3 integrates the individual regional indices to develop a network capital index for the Mexican States (Federal Entities) and ends with section 4 where comments and research findings on the usefulness of the concept and its implications for regional development policies are presented.

2. Methodology for measuring *network capital*

2.1. Theoretical framework of network capital

Network capital is defined as "*consisting of investments in strategic and calculative relations with other firms and organizations in order to gain access to knowledge to enhance expected economic returns, principally via innovation*" [1,5] and the authors identify the elements that make up network capital on to the following equation:

$$W(t)_L = \overline{Cs_{L,t}}^{\delta} \cdot \overline{Cex_{L,t}}^{\xi} \cdot \overline{Cm_{L,t}}^{\tau} \cdot h \cdot \sum_{k=1}^{n} C_{L,t}^{n}$$

where $W(t)_L$ is the value of the Network Capital in region "L" in time "t"; $\overline{Cs_{L,t}}^{\delta}$ the average value of Superiority of Knowledge accessed in region "L" in time "t" and relative importance "δ"; $\overline{Cex_{L,t}}^{\xi}$ the average value of Exclusivity of Knowledge accessed in region "L" in time "t" and relative importance "ξ"; $\overline{Cm_{L,t}}^{\tau}$ the average value of Miscibility of Knowledge to be used (mixed) with other knowledge and/or areas of knowledge in region "L" in time "t" and relative importance "τ"; h the knowledge absorptive capacity and $\sum_{k=1}^{\eta} C_{L,t}^{\eta}$ the value of strategic network connections created by the firm in region "L" in time "t" and relative importance "η".

[10] use panel data regression techniques from empirical data of UK regions, show that the availability of network capital and knowledge flows in intra- and inter-regional networks are significantly associated with regional growth rates.

The data used by Huggins and Thompson for their research come from specific databases for the United Kingdom, and their equivalents for Mexico either do not exist or are not available. Therefore, the following sections of this paper present an empirical alternative to the data and approach for calculating regional network capital used by Huggins and Thompson [10].

2.2. Measurement of the elements that make up the network capital

2.2.1. Qualities of knowledge

Determining the value of knowledge is a very complex task that can be simplified if its objective is reduced. In the case presented in this article, the objective is to identify the qualities of knowledge that contribute to improve innovation processes by increasing network capital; as Huggins and Thompson did, this research uses the concepts identify by them: superiority, exclusivity and miscibility.

The concepts uses are like follows: It is said that knowledge is *superior* to others if it emerges from collective processes under an intentional effort, which is also characterized by its partial appropriation and reflects the participation and contribution of interactive agents to access and assimilate it [11–14]. *Exclusive* knowledge is that which is an almost private good with high levels of natural appropriation [11]. *Miscible* or mixable knowledge is that which is capable of being combined with different knowledge from different sources or when some units of knowledge can be applied in a variety of contexts [1,15].

With these conceptualizations about the quality of knowledge it is possible to use a rubric that identifies the inter-organizational characteristics of the regional flow of knowledge generated with the expectation of making innovations (see Table 1).

The answers to the questions from superiority and exclusivity come from "Section XII. Technological maturity of the firm" in Research and Technological Development Survey [16] on the years 2012, 2014 and 2016; this survey is conducted by INEGI [17] in all 32 states of the Mexican Republic with a sample frame of 57,746 companies with 20 or more workers and 1201 institutions of higher education, private non-profit and government institutions. The survey includes mining, agriculture, manufacturing, construction services, electricity and services activities; the sample size considers a confidence level of 95%, a relative error of 9% and an expected non-response rate of 20%; it also uses the methodology described in the OECD's Frascatti, Canberra and Oslo manuals. Regarding to the miscibility of knowledge the data come from Annual Reports of the Mexican Institute of Industrial Property [18], all the data were incorporated into the model developed in this

Table 1
Evaluation of the qualities of knowledge.

Qualities		Characteristics of the company that generates and/or develops Knowledge
Exclusivity (*Cex*)	Exc1	Acquires licenses for products or processes or buys machinery and equipment to expand or upgrade its production processes and starts it up without modifications
	Exc2	Acquires licenses on products or processes or buys machinery and equipment, and assimilates them by documenting the aspects related to these technologies
	Exc3	Adapts and modifies technologies on products or processes, machinery or equipment acquired in order to establish higher levels of efficiency in production
Miscibility (*Cm*)	Misc1	Generates or develops its own technology for the exclusive use of the company or companies of the same group to which it belongs
	Misc2	In addition to generating or developing its own technology, the company sells the technology to other companies
Superiority (*Cs*)	Sup1	Patents per 100 thousand inhabitants of the Economically Active Population
	Sup2	Models Profit per 100 thousand inhabitants of the Economically Active Population
	Sup3	Industrial Designs per 100 thousand inhabitants of the Economically Active Population

Source: Own elaboration based on ESIDET 2012–2016 and IMPI Annual Reports 2012–2016

research by an integrated indicator named "knowledge qualities" ($Icc_{i,t}$), which identifies the superiority, exclusivity and miscibility of the knowledge generated in some Mexican State "i" and the year "t" and aimed at making innovations.

The answers to the questions about Exclusivity and Miscibility are dichotomous variables (yes/no) and the aggregated for each State is the number of firms that answer "yes"; in order to avoid size population bias, the total number used is per 100 thousand inhabits of the Economically Active Population. The $Icc_{i,t}$ was obtained using the Principal Component Analysis technique (PCA) with the annual data of each State (i = 1,2, … 32) in the period 2012–2016 (t = 1,2,..5). The correlation matrix between variables used is shown on the Table 2 and the results of Bartlett's test of sphericity and Kaiser-Meyer-Olkin's measure of sampling adequacy (KMO) test are shown on Table 3.

The indicator of knowledge qualities $Icc_{i,t}$ obtained, is used to create a "Index of Qualities of Knowledge" ($Iqk_{i,t}$) shown on Table 4, this index uses normalized values (scale 0 to 100), the method used for normalization is the max-min, where the maximum value (100) is obtained by the State with the "best" value for the indicator, while the minimum value (0) is obtained by the State with the "worst" value.

$$Component\ Index = \frac{absolut\ value - minimum\ value}{maximum\ value - minimum\ value}$$

On Table 4, is could be seen that 8 Mexican's States are within the top 10 best performing for all five years that data is available: Nuevo Leon, Mexico City, Mexico, Queretaro, Jalisco, Coahuila, Guanajuato y Puebla, nevertheless, the differences between the States within the top ten are from 82.82 to 84.26 for all five years analyzed, as opposed to the 10 worst performing States whose differences are less than 5.4 points in all 5 years analyzed.

2.2.1.1. Some comments on data used. The purpose of this research is to capture the concepts of Network Capital at a regional level; however, the data used does not capture the qualities of the knowledge generated or used in micro and small businesses since the survey used is directed at companies with more than 20 workers, and although in Mexico 99% of the companies have fewer than 50 workers, 95.4% of them do not participate in global value chains [19], so it is unlikely that their contributions to regional Network Capital will be significant. Some of the characteristics of this type of company are shown in Table 5.

The data obtained from ESIDET satisfactorily capture the concepts of exclusivity and miscibility in terms of meaning, temporality, geographical coverage and sectorial representativeness. The concept of superiority of knowledge is more difficult to capture since an invention requires time to reach the necessary levels of maturity to obtain returns on investment and although in Mexico the cost of the procedures to obtain industrial property rights (patents, utility models and/or industrial designs) is low, the typical time of the procedures lasts between 3 and 6 years [20], which also does not facilitate the adequate capture of the concept, so further studies on the subject are required. Notwithstanding the above, and in view of the lack of more precise information, the indicators used in this research to try to capture the superiority of knowledge are the most widely accepted, which is why we consider

Table 3
Barttlet's of sphericity and Kaiser-Meyer-Olkin sampling adequacy tests.

Statistic	Value
Determinant of the correlation matrix	0.0000
Chi-square	3542.562
Degrees of freedom	28
p-value (H0: Variables are not interrelated)	0.0000
KMO	0.855

Source: Own elaboration

Table 4
Index of knowledge qualities by Mexican federal entities (2012–2016).

	2012	2013	2014	2015	2016
Aguascalientes	9.49	6.07	11.36	10.60	14.52
Baja California	18.87	17.67	15.41	16.06	18.16
Baja California Sur	1.94	1.01	2.44	1.21	1.33
Campeche	0.00	0.00	1.36	0.00	5.32
Ciudad de Mexico	**100**	**100**	**100**	**100**	**100**
Chiapas	4.06	3.67	3.48	3.01	5.04
Chihuahua	16.89	16.67	17.05	16.77	16.73
Coahuila	18.82	17.06	18.04	17.48	19.08
Colima	4.13	2.47	4.93	6.12	8.87
Durango	5.24	3.83	4.30	1.43	5.38
Mexico	39.56	31.95	30.01	29.54	29.03
Guanajuato	30.64	27.12	26.20	25.37	31.76
Guerrero	2.64	5.64	7.12	4.67	2.89
Hidalgo	3.77	4.56	6.61	6.57	4.37
Jalisco	44.86	36.68	36.34	41.28	44.91
Michoacan	6.65	5.81	4.83	5.39	5.43
Morelos	10.60	12.06	12.33	11.13	10.98
Nayarit	0.53	0.71	0.00	0.77	0.49
Nuevo Leon	59.36	49.00	47.63	47.61	46.14
Oaxaca	1.22	2.18	2.07	1.79	2.87
Puebla	21.55	19.39	19.27	19.18	19.59
Queretaro	15.74	22.02	24.03	26.58	28.66
Quintana Roo	8.41	8.26	9.56	9.97	8.28
Sinaloa	9.93	11.28	13.65	10.41	10.94
San Luis Potosí	8.65	6.90	7.64	6.99	11.20
Sonora	12.57	12.96	19.49	13.06	14.28
Tabasco	3.09	2.58	2.35	2.89	4.03
Tamaulipas	13.79	16.66	13.63	11.26	12.97
Tlaxcala	0.38	0.80	2.18	1.69	0.00
Veracruz	10.79	10.39	10.75	13.53	17.18
Yucatan	12.24	16.03	13.86	14.59	15.03
Zacatecas	3.03	6.41	9.86	4.65	1.43

Source: Own elaboration

Table 5
Some facts about micro and small businesses in Mexico.

Number of workers:	1 to 10	11 to 50
Percentage nationally	95	4
Percentage of job sources	37.8	14.7
Percentage of GNP	14.2	16.1
Percentage of companies that do not provide training	85.8	44.9
Percentage of companies using computer equipment	19.8	84.6

Source: Own elaboration based on ENAPROCE [19]

Table 2
Correlation matrix between variables used to quantify the Quality of Knowledge.

	Exclusivity1	Exclusivity2	Exclusivity3	Miscibility1	Miscibility2	Superiority1	Superiority2	Superiority3
Exclusivity1	1.000							
Exclusivity2	0.996	1.000						
Exclusivity3	0.994	0.996	1.000					
Miscibility1	0.992	0.996	0.997	1.000				
Miscibility2	0.992	0.995	0.994	0.998	1.000			
Superiority1	0.521	0.536	0.527	0.540	0.541	1.000		
Superiority2	0.509	0.526	0.509	0.533	0.545	0.525	1.000	
Superiority3	0.674	0.679	0.662	0.662	0.683	0.604	0.630	1.000

Source: Own elaboration

them to be an acceptable approach to the concept.

2.2.2. Absorptive capacity

Some of the most cited authors in the academic area of Knowledge Absorptive Capacity are Cohen & Levinthal [21] and Zahra & George [22]; who define and analyze it at the firm level as:

"the ability to recognize the value of new, external knowledge, assimilate it, and apply it to commercial ends, i.e. the process of innovation" and "a set of organizational routines and processes by which firms acquire, assimilate, transform, and exploit knowledge to produce a dynamic organizational capability", respectively.

Although only recently has there been a growing recognition that Knowledge Absorptive Capacity is an effective way of maintaining and sustaining a competitive advantage, there is still no academic consensus on how to measure it, is usual for it to be measured at the firm level using surveys aimed at managers and middle managers as in Ref. [23]; in this research however, it is necessary to extend the concept to the regional level for which it is more appropriate to use a perspective that involves regional indicators.

Juknevičienė [24] states that the knowledge absorptive capacity should be analyzed from a regional perspective and that it is constituted of three elements: (a) access to knowledge (information, human knowledge, intelligent goods), (b) the capacity to anchor knowledge (understand the accessed knowledge, to identify its value and apply it in a local environment) and (c) the capacity to disseminate knowledge and innovations (in order to increase the value added by improved, innovative activities). Juknevičiene [25] draws up a list of variables that are related to the three key components and distinguishes between the causes and consequences of each component.

The present research has identified the proxy indicators to the proposals of [24,25] and they are shown in Table 6. The databases used are in the public domain and come from the Ministry of Economy, the National Registry of Scientific and Technological Institutions and Companies (RENIECYT-CONACYT), the Annex to the General Report on Science, Technology and Innovation in 2016 of the CONACYT, the Statistical Yearbooks on Higher Education of the National Association of Universities and Higher Education Institutions (ANUIES), the National Survey on Occupation and Employment (ENOE), the Economic Information Bank (BIE) and the National Statistical Directory of Economic Units (DENUE) of the INEGI.

The Regional absorptive capacity was quantified using an indicator generated by the Principal Component Analysis technique (PCA), using the annual data of each Federal Entity (i = 1,2, … 32) in the period 2012–2016 (t = 1,2,..5), additionally regression techniques were used for interpolation and extrapolation of the unavailable data, and using the standardization formula, a "*Standardized Absorptive Capacity index*" ($Iac_{i,t}$) is obtained and applied to each Federal Entity. The correlation matrix between variables used is shown on annex 1 and the results of KMO test and Barttlet test of sphericity are shown in Table 7 and indicate that the sample is suitable to use the PCA technique, in the same way, the results of ($Iac_{i,t}$) are shown in Table 8 and as can be seen, there are 9 States that are within the 10 with the best performance for all five years that data is available: Nuevo Leon, Mexico City, Jalisco, Baja California Sur, Baja California, Quintana Roo, Sonora, Queretaro, nevertheless, the differences between the States within the top ten are from 60.05 to 68.89 for all five years analyzed, as opposed to the 10 worst performing States whose differences are from 13.75 to 21.1 points in all 5 years analyzed.

2.2.2.1. Some comments on data used. Although it is not widely accepted how to measure the concept of the absorptive capacity of knowledge, that the measurement can be biased by the tourist regions where there are more flights or more ATMs and that it does not allow the capture of interregional influences, the perspective of evaluating the absorption capacity of knowledge at the regional level does allow limiting the subjective opinions of the surveys directed to the personnel of the firms and represents an acceptable approach to be used in the objective of this research, additionally and to avoid the bias by the size of the population the indicators used are prorated per 100 thousand inhabitants.

Table 6
Absorptive capacity indicators for Mexican's states.

Access	ACC1	Percentage of total households that have cell phones
	ACC2	Percent of total households with Internet access
	ACC3	Point of sale terminals per 100 thousand adults
	ACC4	ATMs per 100 thousand adults
	ACC5	Contracts using mobile banking per 100 thousand adults
	ACC6	Number of flights that land and take off per 100 thousand inhabitants of the Economically Active Population ("EAP")
	ACC7	Passengers landing and taking off per 100 thousand inhabitants of the EAP
	ACC8	Number of Scientific and Technological Institutions and Companies (RENIECYT) per 100 thousand inhabitants of the EAP
	ACC9	Number of Public Research Centers recognized by CONACYT per 100 thousand inhabitants of the EAP
	ACC10	Number of Private Research Centers per Entity per 100 thousand inhabitants of the EAP
	ACC11	Number of Technological Parks per thousand inhabitants of the EAP
	ACC12	Proportion of the Federal Entity's GDP in the total national GDP. (Percentage)
Anchoring	ANC1	Researchers who are members of the National System of Researchers (SNI) per 100 thousand inhabitants of the EAP.
	ANC2	Number of CONACYT National Postgraduate Quality Programs (PNCP-CONACYT) per 100 thousand inhabitants of the EAP
	ANC3	Number of Graduate Scholarships per 100 thousand inhabitants of the EAP
	ANC4	Graduates of Postgraduate Studies per 100 thousand inhabitants of the EAP
	ANC5	Percentage of Workers in the Service Sector in the EAP
	ANC6	Percentage of Population 20–59 with Upper Middle and Higher Education
	ANC7	Percentage of population 25 years and older with education, technical, normal or higher
	ANC8	Investment: Pesos per person of the EAP
	ANC9	Foreign Direct Investment per 100 thousand inhabitants of the EAP
	ANC10	Economic Complexity of Innovation Sectors per 100 thousand inhabitants of the EAP
Diffusion	DIF1	Number of Projects between Ministry of Public Education and CONACYT (SEP-CONACYT) x100 thousand of the EAP
	DIF2	Number of Projects development under the Innovation Incentive Program (PEI-CONACYT) x100 thousand of the EAP
	DIF3	Number of trademark applications x100 thousand of the EAP
	DIF4	Number of trademark registrations x100 thousand of the EAP

Source: Own elaboration based on Juknevičienė's works [25,26] and [24]

Table 7
Barttlet's of sphericity and Kaiser-Meyer-Olkin sampling adequacy tests.

Statistic	Value
	Access
Determinant of the correlation matrix	0.0000
Chi-square	4748.128
Degrees of freedom	325
p-value (H0: Variables are not interrelated)	0.000
KMO	0.831

Source: Own elaboration

2.2.3. Value of strategic network connections

The value of the connections strategically created by the firm in the region "*L*" and in time "*t*" and that are also oriented to improve the expected economic return through innovation ($\sum_{k=1}^{n} C_{L,t}^{n}$), on this research,

Table 8
Index of absorptive capacity by Mexican federal entities (2012–2016).

	2012	2013	2014	2015	2016
Aguascalientes	33.79	37.23	32.87	37.77	40.75
Baja California	33.59	33.98	32.98	38.11	39.95
Baja California Sur	45.21	44.69	39.50	45.79	47.87
Campeche	23.22	24.41	24.79	33.34	31.19
Ciudad de Mexico	**100**	**100**	**100**	**100**	**100**
Chiapas	3.98	5.74	1.35	6.50	2.21
Chihuahua	25.59	26.21	24.52	28.81	29.47
Coahuila	31.11	29.55	30.04	35.29	37.68
Colima	30.04	30.61	47.70	51.94	51.64
Durango	14.17	14.25	14.42	18.92	21.10
Mexico	19.56	22.49	22.35	26.70	26.62
Guanajuato	16.13	18.45	18.18	24.25	23.41
Guerrero	0.00	2.19	1.85	6.51	5.92
Hidalgo	8.13	12.13	11.02	16.00	13.02
Jalisco	32.99	36.04	39.47	45.73	49.21
Michoacan	9.96	11.46	10.00	14.57	13.15
Morelos	29.45	31.39	27.64	31.53	33.61
Nayarit	15.62	21.28	17.75	22.40	21.11
Nuevo Leon	46.30	46.08	47.26	55.26	61.04
Oaxaca	0.49	1.43	0.00	5.17	0.00
Puebla	11.46	13.95	12.79	18.65	17.90
Queretaro	34.56	38.87	34.52	42.98	46.24
Quintana Roo	41.04	42.48	44.61	51.43	55.75
Sinaloa	23.39	25.44	25.52	31.71	35.22
San Luis Potosí	20.06	20.58	17.25	22.78	21.99
Sonora	32.24	34.58	34.32	38.57	40.44
Tabasco	17.26	18.43	19.59	21.24	23.87
Tamaulipas	24.83	23.53	25.25	29.42	28.95
Tlaxcala	7.28	9.21	8.87	13.00	11.63
Veracruz	13.96	15.62	14.89	18.59	16.19
Yucatan	26.37	27.59	24.74	31.77	32.53
Zacatecas	7.00	8.75	7.29	12.62	8.99

Source: Own elaboration

is calculated as the sum of the investments made in projects aimed at innovation activities in the i-th State in the " t" year ($\sum_{k=1}^{n} inv_{k,i,t}$) and is integrated by the sum of the investment on Science, Technology and Innovation by each State, the investment on PEI projects at State level and investment on Basic Science on each State. The data used come from the Annex to the General Report on Science, Technology and Innovation of the CONACYT and the Innovation Stimulus Program (PEI) of the National Council for Science and Technology [27]. The associated indicator was obtained by averaging all variables and normalizing it, additionally it was prorated per 100 thousand inhabitants to create the standardized index of "Strategic network" ($Isn_{i,t}$). Table 9 shows the standardized index of the value of connections of the federal entities in the period 2012–2016, and is could be seen that there are 3 Federal Entities whose performance remains within the top 10 during the entire period analyzed: Mexico City, Queretaro and Morelos, nevertheless, the differences between the States within the top ten are from 31.2 to 57.3 for all five years analyzed, as opposed to the 10 worst performing States whose differences are less than 21.45 points in all 5 years analyzed.

2.2.3.1. Some comments on data used. The definition about Research and experimental Development (R&D) on the Frascatti manual: "Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge including knowledge of humankind, culture and society – and to devise new applications of available knowledge." (OECD, 2014:44–45), as well as their guideless for collecting the expenses on R&D should be the best

Table 9
Index of Value of strategic network connections by Mexican Federal Entities (2012–2016).

	2012	2013	2014	2015	2016
Aguascalientes	69.65	91.62	29.82	71.80	75.19
Baja California	36.22	36.13	36.84	56.27	39.33
Baja California Sur	12.48	22.74	19.86	17.72	42.18
Campeche	54.38	39.88	2.76	42.49	48.86
Ciudad de Mexico	84.46	96.97	**100**	99.40	**100**
Chiapas	0.00	9.13	0.59	10.05	0.00
Chihuahua	32.38	43.32	24.99	45.03	11.64
Coahuila	47.76	68.84	41.62	41.87	28.10
Colima	46.77	66.59	51.02	96.22	99.08
Durango	41.54	56.30	42.70	68.23	59.23
Mexico	63.74	68.45	56.75	46.00	37.42
Guanajuato	29.74	37.66	23.06	35.32	59.33
Guerrero	6.60	10.14	3.53	21.00	20.34
Hidalgo	30.76	38.43	17.16	24.90	14.40
Jalisco	29.68	36.27	17.00	68.31	69.53
Michoacan	17.62	15.19	11.48	21.98	13.99
Morelos	66.61	93.14	52.13	**100**	99.29
Nayarit	18.13	22.47	14.06	27.23	17.17
Nuevo Leon	**100**	96.95	80.95	75.41	45.94
Oaxaca	2.70	1.29	0.00	5.26	33.66
Puebla	14.93	27.95	17.22	21.20	8.65
Queretaro	83.52	**100**	68.58	88.42	85.15
Quintana Roo	16.25	20.16	7.52	12.10	9.66
Sinaloa	43.89	78.90	48.76	77.16	50.10
San Luis Potosí	60.98	68.80	50.43	46.10	28.25
Sonora	49.50	78.56	38.62	60.65	45.08
Tabasco	21.31	21.84	16.16	17.50	6.90
Tamaulipas	11.22	14.32	5.53	8.25	3.81
Tlaxcala	25.43	28.94	3.07	20.53	20.11
Veracruz	5.37	10.21	3.50	10.66	4.81
Yucatan	64.44	69.31	60.70	59.60	39.53
Zacatecas	33.69	47.99	18.23	36.83	35.25

Source: Own elaboration

source of data in order to calculate the Index of Value of strategic network connections, however, for the Mexican case, this information is available just for National level, for that, is not useful for this research, instead, the three types of R&D activities specified on Frascatti Manual were included: basic research, applied research and experimental development. The investment on Science, Technology and Innovation is the investment from the Federal Government on the "i-th" State and the "t-th" year, in the same way, the investment on PEI projects is the amount of investment done by firms and CONACYT and the investment on Basic Science is the mount of investment on Basic Science on each State. As there is no clarity about impact of each investment, as noted by Audretsch & Keilbach [28]; on this research the same impact was considered, this topic should be further researched.

3. Results

3.1. Performance of the indices that make up the network capital

As illustrated, the States indexes are dynamic and their observation over time can be useful to assess the regional performance of knowledge qualities, absorptive capacity of knowledge and investment in strategic network connections. It should be noted that in all three indexes the range of the score among the 10 States within the best performance is greater than the range of the score among the 10 States within the worst performance, which is related to the structural conditions of each State that affect the regional innovation processes that promote economic

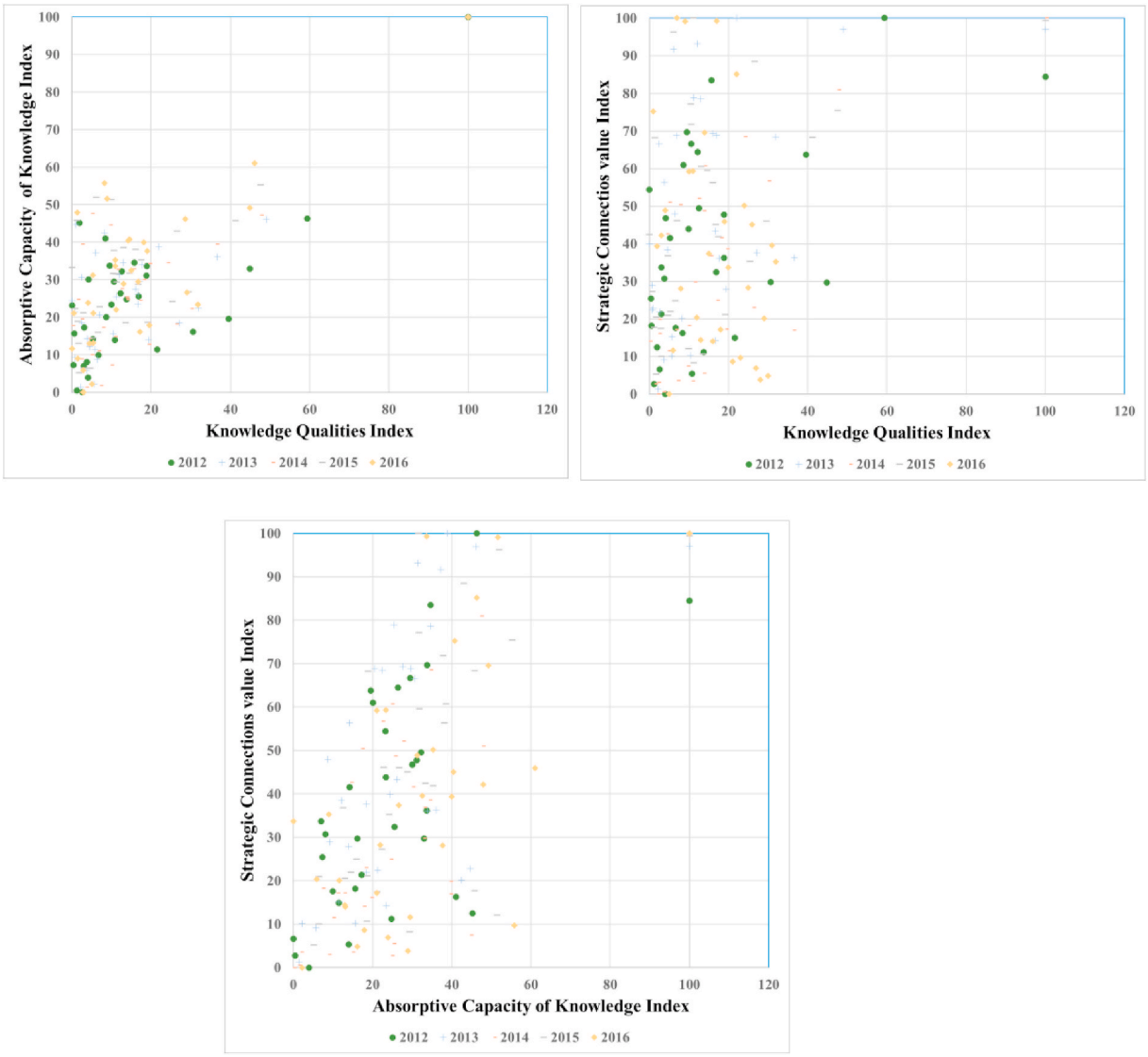

Fig. 1. Scatter plots of Network Capital components.
Source: Own elaboration

Table 10
Index of network capital by Mexican federal entities (2012–2016).

	2012	2013	2014	2015	2016
Aguascalientes	38.75	44.61	24.16	39.72	42.09
Baja California	30.09	28.50	27.91	36.45	30.81
Baja California Sur	19.72	21.89	20.04	21.07	28.74
Campeche	26.14	20.47	9.01	24.81	26.69
Ciudad de México	**100**	**100**	**100**	**100**	**100**
Chiapas	1.30	4.83	1.13	5.88	0.00
Chihuahua	25.16	27.96	21.64	29.78	17.28
Coahuila	33.31	37.96	29.41	31.13	26.51
Colima	27.33	32.56	34.09	51.19	52.04
Durango	20.19	23.92	19.92	29.09	26.80
Mexico	42.30	40.50	35.92	33.69	29.32
Guanajuato	25.75	26.94	21.94	27.87	36.63
Guerrero	1.72	4.64	3.50	10.12	7.48
Hidalgo	13.66	17.33	10.98	15.27	8.38
Jalisco	36.82	35.75	30.46	51.55	53.43
Michoacan	10.65	9.59	8.14	13.41	8.65
Morelos	36.51	45.18	30.22	47.28	46.67
Nayarit	10.67	13.69	9.98	16.25	10.77
Nuevo leon	71.87	64.13	58.32	59.26	49.83
Oaxaca	0.00	0.17	0.00	3.41	10.00
Puebla	15.55	19.44	15.85	19.15	13.28
Queretaro	46.21	53.49	41.98	52.44	52.19
Quintana Roo	21.89	22.73	20.01	24.03	22.70
Sinaloa	26.00	38.01	28.82	39.42	30.41
San Luis Potosí	30.45	31.40	24.58	24.82	18.51
Sonora	32.10	41.59	30.33	37.06	31.61
Tabasco	13.30	13.14	12.09	13.31	9.41
Tamaulipas	16.22	17.12	14.21	15.76	13.14
Tlaxcala	10.25	11.81	4.04	11.15	8.36
Veracruz	9.18	10.87	9.09	13.69	10.57
Yucatan	35.23	37.09	32.64	34.94	27.27
Zacatecas	14.04	20.07	11.18	17.50	13.12

Source: Own elaboration

development based on innovation. The scatter plot of the three indexes is shown in Fig. 1 and it can be seen that there could be a linear relationship that allows the construction of a Network Capital index as a linear relationship of the three components.

3.2. Network capital index

The authors of the concept of network capital quantify it at the firm level and then integrate it at the regional level. However, for this research, disaggregated information is not available at the company level, and since scatter plots show the existence of a possible linear relationship, we prefer to quantify Network Capital using an index that we define as the "Regional Network Capital Index" ($RNCI_{i,t}$), which has been defined as:

$$RNCI_{i,t} = \frac{1}{3} Iqk_{i,t} + \frac{1}{3} Iac_{i,t} + \frac{1}{3} Isn_{i,t}$$

Fig. 2. Network Capital index for Mexican Federal Entities (2016).
Source: Own elaboration

where "*Iqk*" is the Regional Knowledge Qualities index; "*Iac*" is the Regional Absorptive Capacity index; the "*Isn*" is the Strategic Connections investments index and the subscripts "*i*" and "*t*" denote respectively the State and the year evaluated for all cases. With the data available for this research, it is not possible to establish a weighting of the elements that compose the regional network capital, for which reason, it was decided to give them the same importance under the condition that in subsequent investigations there are elements that clarify this area of opportunity.

Table 10 shows the Network Capital Index by Federal Entity for the period 2012 to 2016, in this table (although with a wide range of values) there are 5 States that are within the 10 with the best performance for all five years that data is available: Nuevo Leon, Mexico City, Morelos, Queretaro and Sonora and Fig. 2 show a map whit the Network Capital index by Federal Entity exclusively for the year 2016.

4. Conclusions

The results obtained in this empirical alternative to capture the theory covered by Ref. [1] show evidence that the Network Capital could be evaluated using the data available locally at regional level, and it could be useful in the research about regional development based on knowledge.

This study has shown that at less at the period analyzed (5 years), the relative value of Network Capital is higher in Mexican entities that are located in more developed regions and that the gap between them and marginalized States is very large, that is, the difference in knowledge qualities, knowledge absorption capacity and the value of network connections reflects intense structural differences, and those differences have a intense relationships with the regional development based on knowledge. This differences could be typical on non-innovation nations.

Unlike studies that use questionnaires that may be influenced by the qualitative perceptions of the interviewees, such as that of Lau & Lo [29]; this study uses public access indicators, which minimizes the bias of perceptions, and in spite of coming from different sources, the three indicators constructed to integrate network capital coincide in reflecting the structural conditions of the States.

And although the analysis of the structural conditions can be useful for the design of policies that promote the development based of knowledge of the most backward states, the present work also has limitations since it is of exploratory character and at this moment it does not try to establish causal relationships.

Despite its possible limitations, this work has shown evidence that the concept of Network Capital can be useful in the academic study of regional development based on knowledge and innovation, which invites to deepen in this area of knowledge.

Credit author statement

Edna María Villarreal Peralta: Methodology, Formal analysis, Resources, Writing – original draft, Writing – review & editing, Visualization, Mario López López: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Visualization, Rubén Alan García Tapia: Methodology, Resources.

Annex 1.

Matrix of correlations between the components of the regional absorption capacity of knowledge.

	ACC1	ACC2	ACC3	ACC4	ACC5	ACC6	ACC7	ACC8	ACC9	ACC10	ACC11	ACC12	ANC1	ANC2	ANC3	ANC4	ANC5	ANC6	ANC7	ANC8	ANC9	ANC10	DIF1	DIF2	DIF3	DIF4
ACC1	1.00																									
ACC2	0.70	1.00																								
ACC3	0.54	0.70	1.00																							
ACC4	0.63	0.80	0.90	1.00																						
ACC5	0.41	0.46	0.35	0.38	1.00																					
ACC6	0.33	0.51	0.55	0.56	0.57	1.00																				
ACC7	0.29	0.51	0.64	0.63	0.53	0.96	1.00																			
ACC8	0.35	0.34	0.39	0.33	0.08	−0.15	−0.12	1.00																		
ACC9	0.30	0.30	0.32	0.30	−0.03	−0.04	−0.04	0.64	1.00																	
ACC10	0.18	0.32	0.22	0.27	0.24	0.39	0.39	0.33	0.21	1.00																
ACC11	0.34	0.25	0.10	0.14	0.12	−0.16	−0.14	0.41	0.28	0.23	1.00															
ACC12	0.24	0.36	0.21	0.32	0.52	0.85	0.74	−0.31	−0.14	0.39	−0.20	1.00														
ANC1	0.24	0.46	0.37	0.38	0.39	0.59	0.60	0.25	0.09	0.66	0.06	0.53	1.00													
ANC2	0.19	0.17	0.15	0.19	−0.14	0.10	0.10	0.30	0.60	0.46	0.14	0.08	0.32	1.00												
ANC3	0.17	0.24	0.17	0.20	−0.01	0.19	0.19	0.30	0.57	0.52	0.06	0.15	0.42	0.89	1.00											
ANC4	0.18	0.21	0.08	0.19	0.18	0.14	0.12	0.40	0.26	0.53	0.14	0.17	0.32	0.38	0.48	1.00										
ANC5	0.44	0.44	0.62	0.63	0.22	0.30	0.36	0.13	0.14	0.00	0.04	0.22	0.25	−0.01	−0.02	−0.08	1.00									
ANC6	0.60	0.71	0.63	0.66	0.58	0.64	0.61	0.33	0.23	0.28	0.14	0.46	0.54	0.08	0.22	0.24	0.38	1.00								
ANC7	0.63	0.76	0.60	0.76	0.48	0.65	0.60	0.31	0.25	0.49	0.20	0.59	0.58	0.26	0.29	0.35	0.48	0.77	1.00							
ANC8	0.57	0.68	0.60	0.78	0.50	0.64	0.63	0.28	0.23	0.51	0.16	0.62	0.57	0.23	0.22	0.27	0.49	0.61	0.86	1.00						
ANC9	0.01	0.17	0.14	0.16	−0.11	−0.03	0.01	0.05	0.07	−0.03	0.18	−0.05	0.09	−0.02	−0.04	−0.09	0.08	−0.04	0.06	0.14	1.00					
ANC10	0.22	0.12	−0.11	0.07	0.04	−0.19	−0.24	0.12	−0.02	0.10	0.18	0.01	0.06	0.05	−0.01	−0.01	0.19	0.05	0.20	0.26	0.09	1.00				
DIF1	0.20	0.21	0.21	0.20	−0.04	0.17	0.17	0.36	0.64	0.48	0.10	0.10	0.38	0.88	0.92	0.38	0.04	0.19	0.29	0.23	−0.06	0.01	1.00			
DIF2	0.18	0.04	0.07	0.13	−0.20	−0.11	−0.11	0.38	0.60	0.33	0.16	−0.13	0.09	0.81	0.66	0.36	0.00	−0.03	0.13	0.14	−0.10	0.13	0.71	1.00		
DIF3	0.25	0.45	0.37	0.44	0.55	0.68	0.68	−0.05	−0.11	0.44	0.04	0.63	0.55	0.02	0.15	0.22	0.20	0.44	0.57	0.61	0.10	−0.02	0.10	−0.16	1.00	
DIF4	0.26	0.46	0.40	0.47	0.65	0.83	0.82	−0.06	−0.11	0.53	−0.01	0.77	0.69	0.04	0.16	0.25	0.22	0.54	0.65	0.70	0.05	−0.06	0.12	−0.16	0.90	1.00

Source: Own elaboration

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