Biplot analysis of Mexico's State Competitiveness Index

Análisis biplot del Índice de Competitividad Estatal de México

Análise biplot do Índice de Competitividade Estadual do México

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Abstract

Competitiveness is fundamental to the economic and social development of a country, and is determined by factors such as innovation, efficiency, productivity and quality; in addition, some agents in the environment influence it. Measuring and analyzing competitiveness is a matter of great importance for government, entrepreneurs and academics, as its results allow better decision-making, as well as the design of public policies that encourage it. The Mexican Institute for Competitiveness is a non-profit civil association that since 2006 has been publishing the State Competitiveness Index, composed of ten subindexes, to measure competitiveness at the state level. This Institute has presented several analyses based on this

index1. However, there are some multivariate statistics tools that can provide additional information to take advantage of other aspects of this information. The biplot is an exploratory graphical technique that allows to reduce the dimension of the space in which relationships between analysis units and variables that you want to study in them are examined. This reduction makes it easy to detect units that have similar characteristics related to the considered variables. It is also a tool for visualizing correlations or independence between variables studied in the analyzed data group. Finally, it can be used to establish the extent to which the variables explain the behavior of each individual in relation to the studied phenomenon. The objective of this work was to present a biplot analysis of the State Competitiveness Index prepared by the Mexican Institute for Competitiveness. This analysis allowed to visualize the relationships between the subindexes used to calculate this index, and also allowed to observe graphically the extent to which the factors used in the construction of State Competitiveness Index explain the competitiveness of each federal entity. In this research the biplot method was used to analyze the State Competitiveness Index 2018 database. Among the most important results is the fact that competitiveness in Mexico is explained by two factors: Inclusive and sustainable economic and social development and Reliable political and legal framework. It also turned out that there is correlation between some of the subindexes used by the Mexican Institute for Competitiveness, such as Factors market, Innovation in the economic sectors and Stable economy. On the other hand, some indicators such as Reliable and objective law system and Innovation in the economic sectors are independent of each other. Regarding the competitiveness of the states, it could be observed that the competitiveness of the first three places in the State Competitiveness Index 2018 can be attributed to strengths in very different areas for each of these three states, as shown by the results of the biplot analysis. It is concluded that this type of analysis facilitates the understanding of the factors that define the competitiveness of states, including the relationships between the indicators used to measure it and how they determine the competitiveness of each state. This kind of information can be used as an important auxiliary in the design of public politics appropriate to the particular situation of each federal entity in order to attract more investment and contribute to the improvement of the quality of life of its inhabitants.

Keywords: data visualization, economic competition, socio-economic indicators

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1 See https://imco.org.mx/indice-de-competitividad-estatal-2020/

Resumen

La competitividad es fundamental para el desarrollo económico y social de un país, está determinada por factores como innovación, eficiencia, productividad y calidad; además algunos agentes del entorno influyen en ella. El medir y analizar la competitividad es un tema de gran importancia para el gobierno, los empresarios y los académicos, ya que sus resultados permiten una mejor toma de decisiones, así como el diseño de políticas públicas que la fomenten. El Instituto Mexicano para la Competitividad es una asociación civil sin fines de lucro que desde 2006 publica el Índice de Competitividad Estatal para medir la competitividad a nivel estatal, considerando diez subíndices. Este instituto ha presentado diversos análisis basados en este índice2. Sin embargo, hay algunas herramientas de estadística multivariante que pueden proporcionar información adicional para aprovechar otros aspectos de esta información. El biplot es una técnica gráfica exploratoria que permite reducir la dimensión del espacio en el que se examinan relaciones entre unidades de análisis y variables que se desean estudiar en ellas. Esto permite detectar fácilmente unidades que tienen características similares relacionadas con las variables consideradas. También es una herramienta para visualizar correlaciones o independencia entre las variables estudiadas en el grupo de datos analizado. Finalmente, se puede usar para establecer en qué medida las variables explican el comportamiento de cada individuo en relación con el fenómeno estudiado. El objetivo de este trabajo fue presentar un análisis biplot del Índice de Competitividad Estatal, elaborado por el Instituto Mexicano para la Competitividad. Este análisis permitió visualizar las relaciones que hay entre los subíndices que se utilizan para calcular dicho índice, además de que permitió observar gráficamente en qué medida los factores empleados en la construcción del Índice de Competitividad Estatal explican la competitividad de cada entidad federativa. En esta investigación se utilizó la base de datos del Índice de Competitividad Estatal 2018 y se aplicó el método biplot para analizarla. Entre los resultados más importantes destaca el hecho de que la competitividad en México está explicada por dos factores: Desarrollo económico y social incluyente y sustentable y Marco político y legal confiable. También resultó que hay correlación entre algunos de los subíndices utilizados por el Instituto Mexicano para la Competitividad, como por ejemplo Mercado de factores, Innovación en los sectores económicos y Economía estable. Por otra parte, algunos indicadores como Sistema de derecho confiable y objetivo e Innovación de los

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2 Ver https://imco.org.mx/indice-de-competitividad-estatal-2020/

sectores económicos son independientes entre sí. En relación con la competitividad de los estados, se pudo observar que la competitividad de los tres primeros lugares del Índice de Competitividad Estatal 2018 puede atribuirse a fortalezas en áreas muy diferentes para cada uno de estos tres estados como lo muestran los resultados del análisis biplot. Se concluye que con este tipo de análisis se facilita la comprensión de los factores que definen la competitividad de los estados, incluyendo las relaciones entre los indicadores utilizados para medirla y la forma en la que estos determinan la competitividad de cada estado. Esta clase de información puede emplearse como un auxiliar importante en el diseño de políticas públicas adecuadas a la situación particular de cada estado a fin de atraer más inversión y contribuir al mejoramiento de la calidad de vida de sus habitantes.

Palabras clave: visualización de datos, competencia económica, indicadores socioeconómicos.

Resumo

A competitividade é essencial para o desenvolvimento econômico e social de um país, é determinada por fatores como inovação, eficiência, produtividade e qualidade; Além disso, alguns agentes ambientais o influenciam. Medir e analisar a competitividade é um tema de grande importância para governo, empresários e acadêmicos, uma vez que seus resultados permitem uma melhor tomada de decisão, bem como o desenho de políticas públicas que a promovam. O Instituto Mexicano para a Competitividade é uma associação civil sem fins lucrativos que publica desde 2006 o Índice de Competitividade do Estado para medir a competitividade em nível estadual, considerando dez subíndices. Este instituto tem apresentado várias análises com base neste índice. No entanto, existem algumas ferramentas de estatísticas multivariadas que podem fornecer informações adicionais para aproveitar outros aspectos dessas informações. O biplot é uma técnica gráfica exploratória que permite reduzir a dimensão do espaço em que se examinam as relações entre as unidades de análise e as variáveis a estudar nas mesmas. Isso permite detectar facilmente unidades que possuem características semelhantes em relação às variáveis consideradas. É também uma ferramenta para visualizar correlações ou independência entre as variáveis estudadas no conjunto de dados analisados. Por fim, pode ser utilizado para estabelecer em que medida as variáveis explicam o comportamento de cada indivíduo em relação ao fenômeno estudado. O objetivo deste trabalho foi apresentar uma análise biplot do Índice de Competitividade do Estado,

elaborado pelo Instituto Mexicano para a Competitividade. Essa análise possibilitou visualizar as relações entre os subíndices que compõem o referido índice, além de permitir observar graficamente em que medida os fatores utilizados na construção do Índice de Competitividade Estadual explicam a competitividade de cada federação entidade. Nesta pesquisa, foi utilizada a base de dados do Índice de Competitividade do Estado 2018 e aplicado o método biplot para analisá-la. Entre os resultados mais importantes está o fato de que a competitividade no México se explica por dois fatores: desenvolvimento econômico e social inclusivo e sustentável e um quadro político e jurídico confiável. Também descobriu-se que há uma correlação entre alguns dos subíndices usados pelo Instituto Mexicano para a Competitividade, como Mercado de Fator, Inovação em setores econômicos e Economia Estável. Por outro lado, alguns indicadores como Sistema de justiça confiável e objetivo e Inovação dos setores econômicos são independentes um do outro. Em relação à competitividade dos estados, observou-se que a competitividade das três primeiras colocações no Índice Estadual de Competitividade 2018 pode ser atribuída a pontos fortes em áreas muito distintas para cada um desses três estados, conforme mostram os resultados do biplot análise. Conclui-se que esse tipo de análise facilita o entendimento dos fatores que definem a competitividade dos estados, incluindo as relações entre os indicadores utilizados para medi-la e a forma como determinam a competitividade de cada estado. Esse tipo de informação pode ser utilizado como um importante auxílio no desenho de políticas públicas adaptadas à situação particular de cada estado, a fim de atrair mais investimentos e contribuir para a melhoria da qualidade de vida de seus habitantes.

Introduction

Developing methods to measure and analyze competitiveness has become a growing interest at the governmental, academic, and corporate levels. These methods have become more accessible thanks to international information and communication technologies, facilitating an increased exchange of goods and services worldwide. Therefore, both the public and private spheres recognize the importance of having information on competitiveness to provide insight to all organizations that require such information to make sound decisions and design effective public policies.

"Competitiveness is a determining variable in a nation's economic and social development. It involves factors such as innovation, efficiency, productivity and quality; it is also influenced by other factors that have to do with the environment" (Jiménez-García, López-Lira, Tomta and Pacheco-Olvera, 2011, p. 215) and this refers "to the process of generating and disseminating skills, to the capacities of certain companies and nations to act successfully in a globalized world" (Cabrero, Orihuela and Ziccardi, 2003, p. 1). Therefore, competitiveness has become an indicator of efficiency, permanence in markets, positioning and advantage.

There are currently different methods or indexes for assessing competitiveness. In the case of Mexico, its evaluation showed aspects such as the decline of the economy at the end of the first decade of the 21st century, contrary to what happened with economies such as the Japanese, Chinese or Brazilian (Jiménez-García, et al., 2011).

This document is organized as follows. Aspects of competitiveness including its concept, its application in organizations and in national economies are presented in the first place. Briefly is discussed how competitiveness has been measured at the international level, it is mentioned the problem of competitiveness in Mexico and how it led to the creation of the Mexican Institute for Competitiveness (IMCO, for its acronym in Spanish). The main characteristics of the State Competitiveness Index (ICE, for its acronym in Spanish), developed by IMCO, are noted, highlighting the factors used to integrate it and its advantages. Subsequently, the objective of the biplot methods is described, some applications of it to the analysis of other indexes are mentioned and its theoretical basis are described.

The results obtained when performing the biplot analysis of the ICE 2018 database are presented, describing the relationships between the factors that make it up, the differences and similarities between the federal entities in relation to competitiveness and the factors that best explain the competitiveness of the first and last places of ICE 2018. Finally, the

limitations, strengths and weaknesses of this research are discussed, and the conclusions are presented.

Method
Conceptual aspects on competitiveness

The conceptual framework of competitiveness can be traced back to the 17th century, with David Ricardo, who raised the theory of comparative advantage in 1817, establishing that not only in the event of an absolute advantage will specialization and international trade between two countries be encouraged, but precisely from comparative advantage, countries are more competitive if they specialize in the production of goods that they can manufacture at a relatively lower cost (Buendía, 2013). By linking the concept of competitiveness, the concept of comparative advantages of a given country continued to be linked to specialize in certain productive sectors and establishing that such advantages relate to all those factors that in a country have an abundance, such as "natural resources, geographical situation, workforce, etc., and which favour the production of certain products, goods and/or services" (Barroso and Flores, 2006, p.10).

According to these approaches, competitiveness was related to the possession of comparative advantages of a nation. Today, with globalization that has changed the patterns of innovation and consumption, in addition to a growing use of technology, it has been necessary to rethink this concept. In view of this picture, one can understand why the concept of comparative advantage is no longer a central aspect to boost competitiveness and instead stands at the concept of competitive advantages, which depend on aspects such as productivity and cost reduction. Therefore, they do not have a direct relationship with aspects such as the location of a company or a nation, but "must be developed as a result of research and development, education and training to respond to the particular needs of a particular industry" (Rojas and Sepúlveda, 1999, p.11).

The issue of competitiveness has become more important for approximately four decades and different approaches can now be distinguished to try to conceptualize and measure it in companies and industries (Porter, 1985; Porter, 1991; Romero, 2006), regions (Esser, Hillebrand, Messner and Meyer-Stamer, 1996), cities and nations (Cabrero, Orihuela and Ziccardi, 2003; Brand and Prada, 2003; Sobrino, 2002; Buendía, 2013).

For Jiménez-García, et al. (2011), "Competitiveness is a determining variable in the economic and social development of a nation. It involves factors such as innovation, efficiency, productivity and quality; it is also influenced by other factors that have to do with the environment" (p.215). On the other hand, Cabrero, Orihuela and Ziccardi (2003) point out that competitiveness also "refers to the process of generating and disseminating competences, as well as the capacities of certain companies and nations to act successfully in a globalized world" (p.1).

As can be seen, different authors, thought streams and organizations of national and international scope have helped to propose various definitions of competitiveness from the business level to the national and international level. This is clearly seen in the approach to systemic competitiveness that "analyzes macroeconomic levels, economic development policies, cultural and social factors, from enterprise level to industry scale" (Ibarra, González and Demuner, 2017, p.108).

Authors who are currently analyzing this issue agree that competitiveness involves not only improved production infrastructure but also "a sustained increase in the population's living standards" (Suñol, 2006, p.183).

Measurement of the competitiveness

In recent years, indicators of international competitiveness, developed by various institutions, have become relevant as instruments to measure the capacity of nations to generate sustained and sustainable economic growth, resulting in better living standards for their inhabitants. The most well-known indicators are the Global Competitiveness Index (GCI), developed by the International Institute for Management Development (IIMD) and the Competitiveness Growth Index (CGI) prepared by the World Economic Forum (WEF) (Mexican Institute for Competitiveness [IMCO], 2003).

Competitiveness in Mexico

In recent years "Mexico's competitive position has deteriorated. According to the GCI, between 1999 and 2002, the country went from place 35 to 41, while, according to the CGI, the fall was 14 places: from position 31 in 1999 to position 45 three years later" (IMCO, 2003, p.1).

The Mexican Business Men Council (CMHN, for its acronym in Spanish), concerned about this loss of competitiveness, "undertook an initiative to understand the main reasons behind this phenomenon and lay the foundations for a program to reverse the country's competitive decline." (IMCO, 2003, p.1).

IMCO has noted that Mexico must improve its competitiveness, as it will simultaneously achieve: "participate openly and successfully in international markets, and in turn, increase the income and well-being of its population in all socio-economic strata" (IMCO, 2003, p. v).

Several members of the business sector, driven by these concerns, decided to create the IMCO. Its basic objective is to promote the development of a better environment, which allows Mexico to be more competitive. The publication "Analysis of The Competitiveness of Mexico: Evaluation and Identification of Areas of Opportunity, is the first contribution with that objective" (IMCO, 2003, p. iii).

IMCO, its mission, members, and the organizations with which collaborates internationally

The Mexican Institute for Competitiveness A.C. (IMCO), created in 2003, is a non-profit, non-partisan research center whose actions to solve Mexico's most critical challenges are based on evidence. Its mission is to "develop public policy proposals that improve the competitiveness of the country's companies" (Mexican Institute for Competitiveness [IMCO, for its acronym in Spanish], 2006). And its objective is to "propose public policies and viable actions and influence their implementation" (Mexican Institute for Competitiveness [IMCO], 2019a, par. 1). As can be seen when reviewing IMCO´s mission, it is interested in contributing to the generation of information that allows knowing the situation in the country. From the results identified by this institute, it has been possible to know different factors that determine the position of Mexico and each of its states. On the other hand, based on the results obtained, the IMCO not only generates information, but later proposes public policies related to the problems or deficiencies detected.

IMCO's Board of Directors is made up of several actors, including managers from different business groups, consultants, national health institutes, business chambers, higher education institutions, NGOs and some civil associations.

Among its objectives, in addition to promoting the development of a better environment that allows the country to be more competitive, it aims to promote the competitiveness of Mexico, so it regularly publishes reports focused on the study of Mexico's competitive position through a rigorous quantitative approach. It also publishes reports related to the analysis of competitiveness at the international level and the analysis of state and urban competitiveness in Mexico.

IMCO works primarily with international economic study organizations such as the World Bank, the North American Competitiveness Council (NACC), the World Economic Forum (WEF) and the Organization for Economic Co-operation and Development (OECD) (IMCO, 2019b).

IMCO has also shown interest in analyzing the main obstacles that prevent the country from being more competitive, as well as developing indicators that allow regular monitoring for improved competitiveness. IMCO presents a methodology that explains the competitiveness of a country (Mexican Institute for Competitiveness [IMCO], 2005). IMCO has applied this methodology to measure the competitiveness of 45 countries, including Mexico, using 140 variables. IMCO's competitiveness indexes are assessments of 10 multidimensional factors that combined have the potential to improve the perspectives of Mexico. (IMCO, 2019a, par. 2).

The State Competitiveness Index

Studying competitiveness at the state level allows precise public policies to be designed to detect the country's true development cores. According to IMCO, the latter is determined by those states that systematically present better results in most variables. It also helps potential domestic or international investors, in addition to the governors themselves, understand the extent to which their states contribute to national competitiveness.

Since 2006, IMCO has been presenting its study called the State Competitiveness Index (Ice) biannually. For IMCO, the concept of competitiveness refers to "an entity's ability to attract and retain investment". However, from 2009 it adapted its definition by also considering the ability to attract and retain talent. For his 2012 study it used a total of 88 indicators for the 32 federal entities. The methodology used is the same that was used before for the calculation of its 2009 International Competitiveness Index, where the weights calculated for the ten subindexes correspond to an estimate from 137 indicators of Mexico's

32 federal entities for the period 2000-2006, as well as 48 countries for the period 2001-2007. In order to determine the contribution of each subindex of the ICE to competitiveness, IMCO uses the Principal Component Regression method, taking as dependent variable an average between investment (Gross Fixed Capital Formation) and talent (Percentage of Workers with Higher Education).

Since 2006, IMCO has had changes in its methodology, including elimination, incorporation and measurement changes in indicators and variables, with changes in weighting by indicator, as well as by subindexes.

ICE's main objective is to provide information to design, prioritize and track public policies that promote the competitiveness of states. This is achieved on the basis of a clear definition of competitiveness and the identification of the factors contributing to it.

According to ICE, competitiveness is defined as the ability of cities, states, or countries to generate, attract, and retain talent and investment. Both talent and investment tend to go to places where better economic and social returns are possible. Thus, in an attractive state to talent and investment we can expect a high level of productivity in companies and people, and because of its close bond we can also expect high levels of prosperity and well-being.

To measure this, ICE evaluates both the structural and conjunctural capabilities of states. These capabilities are defined according to economic theory, international experience and common sense. From them, "it was created a set of indicators that grouped together form subindexes, with which the relationship of each factor is characterized with the definition of competitiveness". (Mexican Institute for Competitiveness [IMCO], 2018, p.174). Currently ICE "considers 98 indicators, categorized into 10 subindexes that assess different dimensions of the competitiveness of the 32 states of the country." (IMCO, 2018, p.95). From here, when referring to the subindexes, their short names given by IMCO, which are detailed in the third column of Table 1, will be used in italics.

IMCO describes in detail the methodology used to build ICE and justifies its suitability to measure competitiveness at the state level.

Table 1. Subindexes used by IMCO to measure state competitiveness.

No.	Subindex	What it measures	Short names used by IMCO
1	Reliable and objective law system	The public and legal security environment.	Law
2	Sustainable environmental management	The ability of states to relate sustainably and responsiblely to natural resources and their environment.	Environment
3	Including, prepared and healthy society	The quality of life of the inhabitants, considering inclusion, education and health.	Society
4	Stable and functional political system	The potential of state political systems to be stable and functional.	Political system
5	Efficient and effective governments	How governments are able to positively influence competitiveness of their states.	Governments
6	Factors market	Worker productivity and other essential characteristics of employment.	Factors market
7	Stable economy	The main characteristics of state economies, as well as the credit situation for businesses and families.	Economy
8	Precursors sectors	The financial, telecommunications and transport sectors.	Precursors
9	Taking advantage of international relations	The degree to which states capitalize on their relationship with the outside world to raise their competitiveness.	International relations
10	Innovation in the economic sectors	The ability of states to compete successfully in the economy, particularly in high value-added, knowledge-intensive and cutting-edge technology sectors.	Innovation

Source: own elaboration based on IMCO, 2006.

In 2018, the seventh edition of ICE was published. ICE has a solid methodological base. Its construction uses statistical methods that include factor analysis and principal components analysis with Varimax rotation.

IMCO documents draw conclusions using the maximum or minimum values of the index, or by considering the first and last places in the index. In some cases, some inferences are made about correlations between some of the ten factors considered, but no other methods of multivariate statistics are used.

The biplot method

The biplot is an exploratory graphical technique, applicable to quantitative data, that allows to reduce the dimension of the space in which relationships between units and the variables to be studied in them are examined (Gabriel, 1971; Cárdenas, Galindo and Vicente-Villardón 2007). With the biplot help it can easily be detected those units that have similar characteristics in relation to the considered variables. It is also possible to detect correlations or independence between the variables studied in the analyzed group. Finally, it can be established to what extent the variables explain the behavior of each individual in relation to the studied phenomenon.

Application of the biplot method to the study of some indexes

Biplot has been used to study several important indexes. For example, Gallego, Galindo and Rodríguez (2015) presents a biplot analysis of the Sustainable Society Index, considering as units a sample of 151 countries and as variables the 21 indicators that make up this index. Similarly, Gallego, Rodríguez and García (2013) analyze the Environmental Performance Index using the biplot method in a group of 149 countries, using nine indicators. In Álvarez (2017) a biplot analysis of the Labour Productivity Index of Latin America and the European Union is carried out. Cubilla, Galindo and Nieto (2016) analyze the Global Competitiveness Index using a biplot method in 17 Latin American countries, considering the 12 pillars used to build it. Other applications of this method to analyze some indexes are found in Ortas, Álvarez, Jaussaud and Garayar (2015), Amor, Galindo and García (2017), Egido and Galindo (2015) and in Bei and Cheng (2013).

Theoretical basis of the biplot

According to Gabriel (1971), to build a biplot, in first place, it is considered a matrix A of m rows, n columns and rank two. A biplot of A is obtained from a matrix G of m rows and two columns and a matrix H of n rows and two columns, so that the element in the ith row and jth column of matrix A is equal to the internal product of row i of the matrix G with the j row of the matrix H. Symbolically, this means that

$$A = GH^T,$$

As H^T is the matrix transpose of H. The rows of G are the row effects and the rows of H are the column effects. The matrices G and H are not unique. In the applications of the biplot, these matrices are constructed from the singular value decomposition

$$A = UDV^T,$$

As

1. U is a matrix whose columns are left eigenvectors of A (eigenvectors of AA^T), u_1, u_2
2. D is a diagonal matrix whose elements of the main diagonal are the eigenvalues of AA^T, (which are those of A^TA), $\alpha_1 \geq \alpha_2 \geq 0$.
3. V is a matrix whose columns are the right eigenvectors of A (eigenvectors of A^TA), v_1, v_2.

From this decomposition, Gabriel proposed to define the matrices G and H in one of the following ways:

1. $G = U, H = DV$ (GH biplot).
2. $G = UD, H = V$ (JK biplot).

The graphical representation of the rows of the matrices G and H in the Cartesian plane is known as an exact biplot of A. This representation allows for a quick visualization of the structure of matrix A.

For a matrix A of rank r greater than two, an approximation with a rank two matrix is first constructed. This is again achieved by decomposition into singular values of A and choosing

$$A_{(2)} = U_2 D_2 V_2$$

As matrices U_2, V_2 are obtained from the corresponding matrices U and V of the decomposition into singular values of A by taking their first two columns, while D_2 it is the diagonal matrix with its eigenvalues corresponding to the chosen columns. An approximate biplot of A is, by definition, an exact biplot of $A_{(2)}$.

This biplot method can be applied, in particular, to principal component analysis, considering a matrix A containing information from m units in which n variables are studied, and in which the average of each variable has been subtracted. In this case the biplot not only allows individual observations and their differences to be graphically scanned, but variances, covariance and correlations between variables can also be inspected (Gabriel, 1971). For this, the rows of G are represented as plane vectors (variable markers) and the rows of H as points on the plane (markers of units). The degree of correlation between variables is associated with the angle between their markers. If this angle is close to zero, the variables are highly correlated. On the contrary, if the vectors are orthogonal, there is no correlation between the variables. In the case of individuals, if their markers are close to each other, then they have similar characteristics in relation to the variables studied.

It is important to mention that the quality of the conclusions obtained depends on the biplot chosen. With the GH-biplot it is obtained better goodness of fit in the rows than in the columns, while with the JK-biplot it is better the goodness of fit with the latter.

In order to be able to represent on the same plane the markers of both individuals and variables, Galindo (1986) proposes a new type of biplot, called HJ-biplot. In this case it is proposed as markers for rows the matrix $G = UD$, while for columns $H = DV$ is chosen. It is shown that the goodness of fit in this case is the same for the rows as for the columns, and these are equal to the obtained separately for the GH-biplot and the JK-biplot. This property is what makes it a widely used method to simultaneously study the relationships between the units and the variables to be analyzed (Galindo, 1986). Another property of this type of biplot is that the orthogonal component of a unit relative to one of the variables approximates the value that this variable has in the mentioned unit. In addition, in this type of biplot the length of the column markers approximates the standard deviation of the corresponding variable.

Results

In this research, the HJ-biplot method was applied to analyze the 10 subindexes that make up the ICE 2018 of IMCO in the 32 federal entities of Mexico. The publication of ICE 2018 was made using the data for the year 2016.

Explained variance and axes

Galindo (1986) states that an adequate interpretation of the HJ-biplot requires the standard deviation and the explained variance for each factor to identify the variables responsible for the position of the axes.

Table 2 presents the results of principal component analysis of subindexes that are considered to calculate ICE.

Table 2. Standard deviation and variance explained

Axis	Standard deviation	Variance explained	Accumulated variance
1	23.7467	0.4495	0.4495
2	15.6423	0.1951	0.6446
3	12.0407	0.1156	0.7602
4	9.63378	0.07399	0.83414
5	7.88562	0.04957	0.88371
6	7.60927	0.04616	0.92987
7	5.56715	0.02471	0.95458
8	5.23083	0.02181	0.97639
9	4.71852	0.01775	0.99414
10	2.71193	0.00586	1.00000

Source: own elaboration on the ICE 2018 database, using the R language.

According to the data in table 2, there is a dominant axis, axis one, that explains 44.95% of the variance of the analyzed data, while the second axis contributes with 19.51% of its variance. The first two axes explain 64.46% of this variance, indicating that this percentage of the total information is contained in these two axes. Consequently, this plane can be used to represent the different subindexes that make up ICE and the federative entities analyzed. Table 3 contains the contribution of each subindex to ICE, which makes it possible to know which of them are responsible for the position of the axes.

Table 3. Relative contribution of each factor to the State Competitiveness Index

Variable	Axis 1	Axis 2
Law	-6.46	47.02
Environment	42.47	-7.60
Society	48.89	-0.91
Political system	2.40	36.25
Governments	34.55	29.75
Factors market	28.15	12.20
Economy	35.34	6.08
Precursors	43.20	-17.54
International relations	52.71	-43.09
Innovation	73.21	27.69

Source: own elaboration based on ICE 2018 database, using the R language.

The analysis of contributions to the different axes shows that the first axis is mainly explained by the factors *Society* (48.89), *Environment* (42.47), *Economy* (35.34), *Precursors* (43.20) and *Innovation* (73.21). On the other hand, the second axis is defined by *Political system* (36.25) and *Law* (47.02).

Relationships between subindexes

Figure 1 shows the biplot for the subindexes that make up ICE 2018. It is possible to observe that the horizontal axis is defined by *Society*, *Environment* and *Economy*. These variables are associated with *Including and sustainable economic and social development.* On the other hand, the vertical axis is determined by *Political system* and *Law*. This relates to a *Reliable political and legal framework*.

The angles formed between the vectors allow to detect correlations between the variables. For example, vectors for *Factors market*, *Innovation* and *Economy*, form small angles, indicating that they are correlated. Similarly, there is correlation between the subindexes *Political system* and *Law*.

On the other hand, if the angle between the vectors is close to 90 degrees, the variables are not correlated. This is the case, for example, for *Law* and *Innovation*. Something similar happens with *Political system* and *Environment*.

**Figure 1.** HJ-Biplot of the subindexes that make up ICE 2018
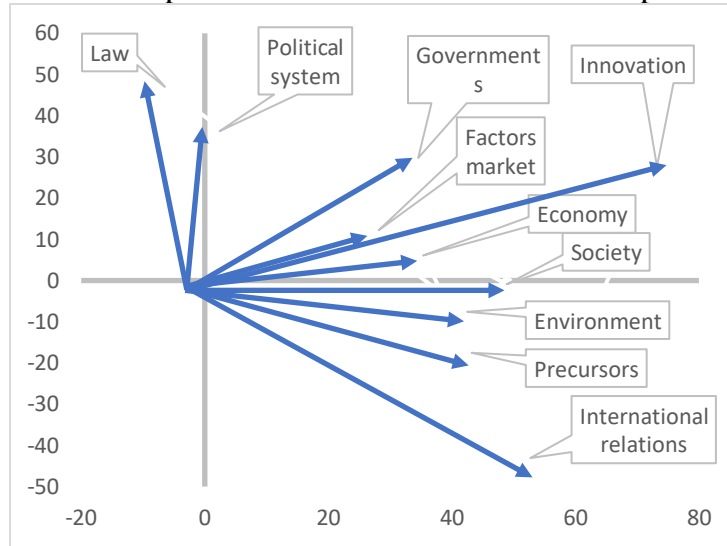
Source: own elaboration based on ICE 2018 database.

Position of the states

Figure 2 shows the biplot of the 32 states of the Mexican Republic. It is observed that the states are distributed in the four quadrants. Those who are represented by points close to each other have similar characteristics in relation to the competitiveness measured through ICE. Examples of this situation include: Zacatecas (26) and Tabasco (27); Guanajuato (15), Puebla (19) and San Luis Potosí (20); Nayarit (21) and Hidalgo (22); Veracruz (28) and Michoacán (29); Querétaro (2), Aguascalientes (4) and Coahuila (5). In several of these cases, their position in ICE is similar. Mexico City (1) is completely separated from the rest of the states and ranks first in ICE 2018. Something similar happens with Chiapas, Guerrero and Oaxaca, which occupy the last places of ICE.

**Figure 2.** HJ-biplot of Mexico's 32 federal entities
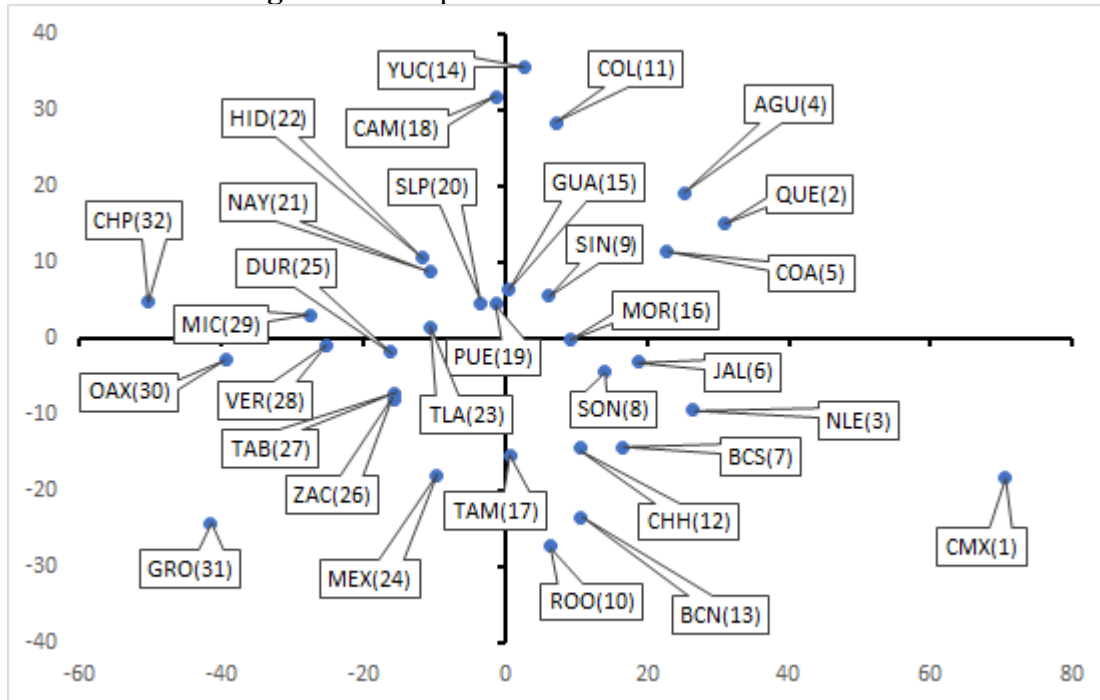
Source: own elaboration with ICE 2018 data. The abbreviations correspond to the 3-digit key of each state, according to ISO 3166-2. The number in parentheses indicates the position of the state in ICE 2018.

It is interesting to note that the first three places of ICE are in quite different positions in this diagram, because while Mexico City and Nuevo León are in the fourth quadrant, Querétaro is in the first quadrant, indicating that the factors that explain its competitiveness are different in these cases. Nuevo León is located in a position closer to the origin of the coordinate system compared to Mexico City. Geographically, these states are located in the center and north of the country.

Subindexes and position of the states

Figure 3 shows simultaneously the HJ-biplot of the subindexes and that of the states. The green dots correspond to the states located in the top ten places of ICE, the red dots to the last 10, and the black dots to the remaining states. From this, it is possible to easily visualize relationships between the states and the factors that define ICE. For example, the greater the component of a point relative to a vector, the greater the contribution of that factor to explain the competitiveness of the corresponding state.

Figure 3. HJ-biplot of the states and subindexes of ICE 2018.
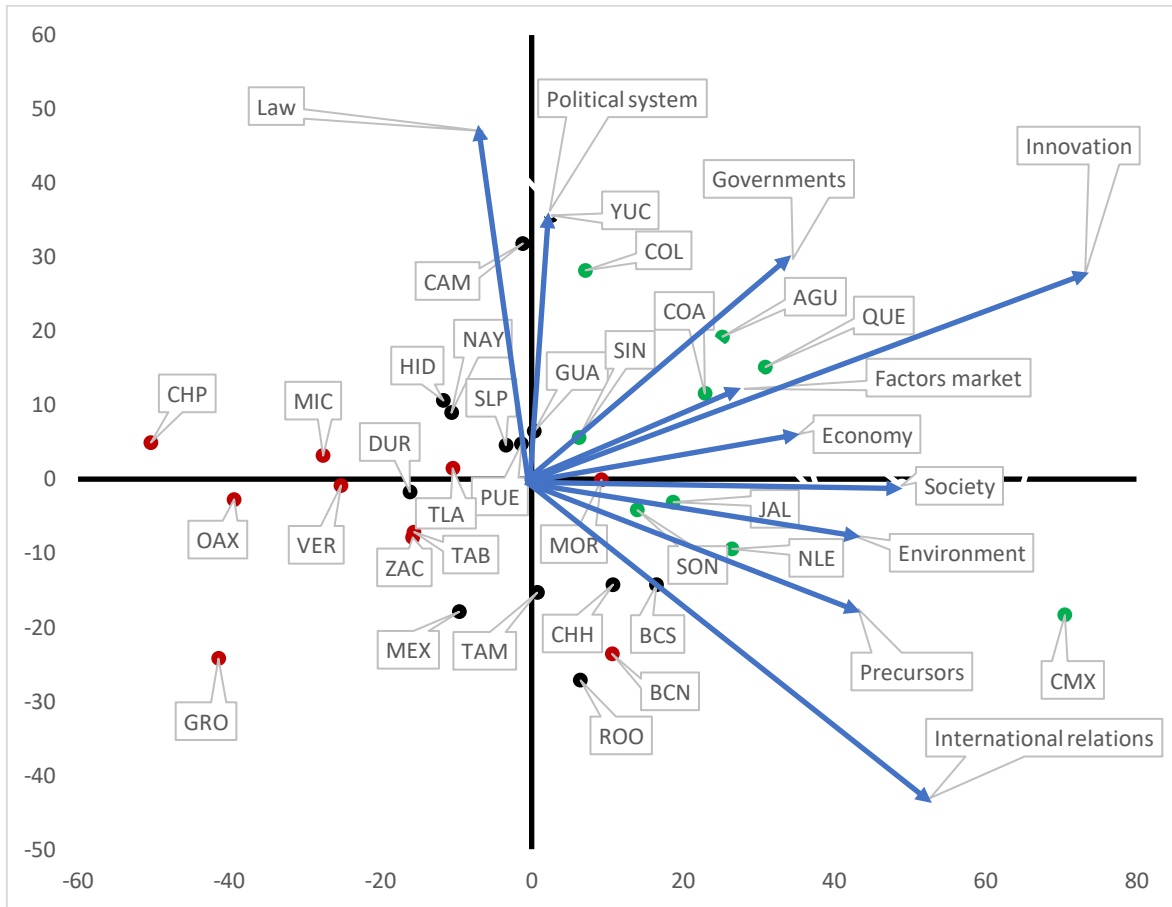
Source: own elaboration with ICE 2018 data. The green dots correspond to the states occupying the top 10 positions in ICE, while the red dots represent the states in the last 10 places of ICE.

According to figure 3, Sonora and Nuevo León are located almost in the direction of the arrow corresponding to *Precursors*, indicating that the competitiveness of these states is largely explained by this subindex. Looking at the orthogonal component of these states with respect to the *Precursors* vector, it is concluded that the contribution of this factor to this explanation is greater in the case of Nuevo León than in that of Sonora. Similarly, Yucatán has an important component in the *Political system* factor.

In contrast to the above, there are some states that are in opposite directions to some arrows. Guerrero is in the opposite direction to *Innovation*, indicating that a weakness in this state lies precisely in this factor. Similarly, Hidalgo and Nayarit are in the opposite direction of *International relations*.

According to the interpretation noted, states located in quadrants I and IV have positive components in almost all ICE subindexes, while states in quadrants II and III have negative components.

It is clear that the top 10 places in ICE, have positive components in almost all subindexes, while the last 10, have negative components. Mexico City, which is the most competitive entity, has negative components in the subindexes *Law* and *Political system*. The second place in ICE, Querétaro, has positive values in the components of these subindexes. Third place, Nuevo León, also has negative components in them.

On the other hand, the less competitive states (Chiapas, Oaxaca, and Guerrero) have negative components in almost all ICE subindexes. Eight of the top 10 states have negative components in relation to *Society*. The only exceptions to this are Baja California and Morelos, which have positive components in several of the subindexes, but still do not have a good ICE position.

Discussion

According to the information provided by ICE and using the biplot method it is possible to easily examine in a two-dimensional chart the factors that best explain competitiveness, in the group of states under consideration. It also allows to determine if there are correlations between the subindexes that define ICE. In addition, it is possible to observe, for each state, what are the competitiveness factors that have well developed and what are those indicators in which they have weaknesses. This type of information can then be supplemented by a statistical analysis of the indicators that have proved most important to explain the competitiveness of a particular federal entity. The graphs obtained in the biplot, although they are built using sophisticated mathematical tools, are usually not presented with numerical values, because their goal is only to facilitate exploratory graphical analysis.

Conclusions

IMCO´s ICE considers ten subindexes to measure the level of competitiveness of Mexico's federal entities. From the IMCO database, which shows the values of these indicators for Mexico's 32 federal entities, the biplot method is applied to obtain graphs that allow easily identifying different types of relationships between states and indicators used to measure their competitiveness. These relationships can help public policymakers, both at the federal and state levels, to have an additional tool to do their job. For example, the biplot has identified two factors that explain the competitiveness of federal entities: *Inclusive and sustainable economic and social development,* on the one hand, and *Reliable political and legal Framework,* on the other. This can be generally useful for rulers to emphasize designing public policies that encourage the development of these factors.

Correlations between the subindexes used to build ICE were also graphically identified, such as *Factors Market, Innovation* and *Economy.* The results suggest that these correlations could be useful, because by encouraging the development of one of these indicators, there may be an impact on the development of others. Similarly, the fact that some subindexes have been independent, such as *Law* and *Innovation,* makes it possible to conclude that the policies impacting one of them will not significantly affect the other, and that therefore both need to be addressed to change competitiveness. However, it is important to consider that these results may have their limitations, because the results obtained with this method are only descriptive and therefore, it is not possible to make statistical inferences about the graphically observed relationships that allow guaranteeing that by enhancing the less developed subindexes, it is certain that the level of competitiveness will increase.

In the case of highly competitive states, it was possible to identify which factors explained their success and have grounds to analyze the policies implemented to achieve this goal. This can serve as a guide for the authorities of other federal entities to carry out similar activities to increase the competitiveness of their states. However, this suggestion must be taken with some reservations because the states that are in the top three places of ICE, occupy different positions on the charts, indicating that their competitiveness has different explanations according to the subindexes used to measure it. On the other hand, in the case of states that have a low competitiveness index, the biplot has identified those indicators of competitiveness in which weaknesses occur and which must therefore be improved to increase their competitiveness.

Future lines of research

In this research an analysis if the ICE using the biplot technique was presented. As the ICE data is available since 2006, the biplot method can be applied to analyze the evolution of this index in different periods of time. Also, given that the ICE contains the values of several indicators in a group of units, other multivariate statistical methods can also be applied to obtain more information about the subindexes considering a specific number of states to be analyzed.

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