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Competitiveness of Mexico in the Technological Innovation Sector: An Assessment of the Patents Granted by Mexican Government

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Competitiveness of Mexico in the Technological Innovation Sector: An Assessment of the Patents Granted by Mexican Government.

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I. ABSTRACT

This paper reviewed the existing literature regarding competitiveness in the technological innovation sector in Mexico. The gaps in the literature were found, and, later, these gaps aided the guidelines of this research. This paper is organized as follows. Section 2 provides a comprehensive literature review in the Mexican context and international context. Section 3 describes aspects of competitiveness in Mexico and the role of R&D organizations and universities related to patent activity. Section 4 covers how the patenting system works in Mexico and provides a description of the Mexican patent system. Section 5 explains the methodology used for this research. Data were obtained from the Mexican Institute of Intellectual Property. Section 6 presents the results obtained after processing data though SPSS software version 21. The paper ends with conclusion and recommendations to improve the current situation of patents in Mexico.

Keywords — competitiveness, patents, Mexico, IMPI, assessment.

II. LITERATURE REVIEW

At the international level, competitiveness is a great way to measure a country's performance. Durand and Giorno (1987) suggest that the capacity for a country's performance can be measured by technological innovation, degree of product specialization, the quality of the products involved, or the value of after-sales service. The academic word of Mansfield (1986) mentions that the patent system is at the heart of any nation's policies toward technological innovation. Acs et al (2002) suggest that the innovative process involved at least one major aspect of the follow (1) R&D expenditures, (2) number of inventions or patents, (3) direct measure of innovation output. More recently, Kaplan (2020) proposes a set of metrics to measure competitiveness such as R&D budget, number of patents, number of active projects in R&D, among others.

In the Mexican context, scholars suggest that Mexico has lost some of its competitive advantages due to low productivity and innovation capacity (Dutrénit et al, 2009). To minimize this, social dumpling practices have been adopted in many areas to build a competitive advantage in the absence of systematic foundations of competitiveness (Covarrubias, 2019). After the implementation of NAFTA, Mexico has developed some technological hubs in cities such as Guadalajara (high-tech), Mexico City (financial), Monterrey (manufacture, high-tech, and education), Queretaro (aerospace), Puebla (automobile), and Guanajuato (automobile). Also, other hubs are present within cities such as Ciudad Juarez (assembly plants), Cancun (tourism), and the Gulf of Mexico area (oil). Despite the fact of the existence of technological hubs in Mexico, it has not been reflected in the increased number of patents granted by the Mexican government.

When analyzing the literature review about Mexican competitiveness, we found out that there is a gap in this respect. Regardless of the effort of Mexican scholars addressing this gap, most of the current literature analyzes the problem like a description of the current state. To identify academic papers, a keyword search was performed using the Scopus database. The keywords used for the search were "competitiveness, innovation, bibliometrics, patent, patent analysis, and Mexico (see fig. 1)."

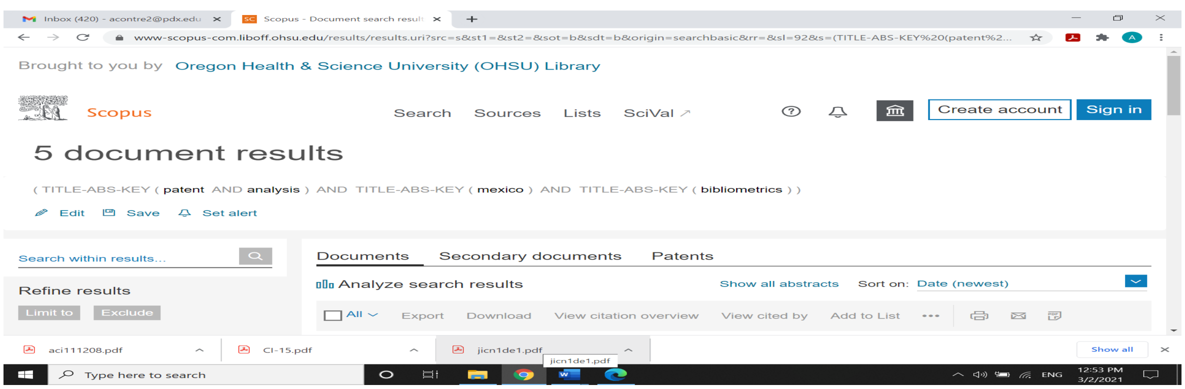

Fig. 1 Results of the keyword search on Scopus

The search showed that only a few academic papers met the selection criteria. Therefore, a second keyword search was done replacing the language from English to Spanish. Most of the current literature regarding competitiveness in Mexico is available in Spanish. Overall, 40 academic papers were found, published in English and Spanish, which include at least one of the keywords either on the keyword section, title, or abstract. These papers were reviewed carefully to identify potential gaps that could provide light in our research. Table 1 shows a summary of the literature review.

Table 1. Literature review of the papers found on the Scopus Data base

Author(s)	Approach	Research
Gregorio-Giménez et al (2017)	Oaxaca Blinder decomposition and estimator proposed by Discroll y Kraay	Determines the actors that explain innovation in Mexican states (population, technology access, education, investment in high education, number of researchers, R&D budget).
Campa (2018)	Data analysis and descriptive statistics	Evaluation of the behavior of patenting activity in Mexico during the industrial protectionist regime of 1940 to 1970 and the economic liberalization regime between 1995 and 2015.
Morales-Sanchez et al (2019)	Descriptive statistics	Comparing technology trends in biotechnology patenting in the United States and Mexico.
Calderon-Martinez (2014)	Regression by groups	Analyzing the factors that influence the production of patents in higher education institutes in Mexico.
Guzmán-Chávez et al (2008)	Dickey–Fuller test	Evaluation of patents and economic growth in Mexico 1980 - 2008
Mendez-Cruz (2014)	Descriptive statistics	Analyzing 20 years of patent activity in Mexico after adopting TRIS agreement.
Restrepo and Alvarado (2016)	Social network mapping	Analysis of co-occurrence words related to patents and innovation.
Valdez-Juarez et al (2018)	Evaluation of a survey by structural equations	Analyze the effects of ICT on KM and their link with innovation and intellectual property to identify how SMEs can achieve higher yields.

The literature review has clearly shown the relationship between competitiveness, innovation, and patents. Also, the lack of studies on this topic opens the opportunity to conduct more research. For this reason, this paper aims to assess the competitiveness of Mexico in the technological innovation sector by the number of patents granted by the Mexican Government from 1993 to 2019.

III. COMPETITIVENESS, R&D, AND UNIVERSITIES IN MEXICO

3.1 Competitiveness. The World Economic Forum publishes every year the Global Competitiveness Report (GCR) which provides a competitiveness annual assessment of the drivers of productivity and long-term economic growth (Schwab, 2019). In its 2019 report, Mexico ranks 34th among forty-three countries (see fig. 2).

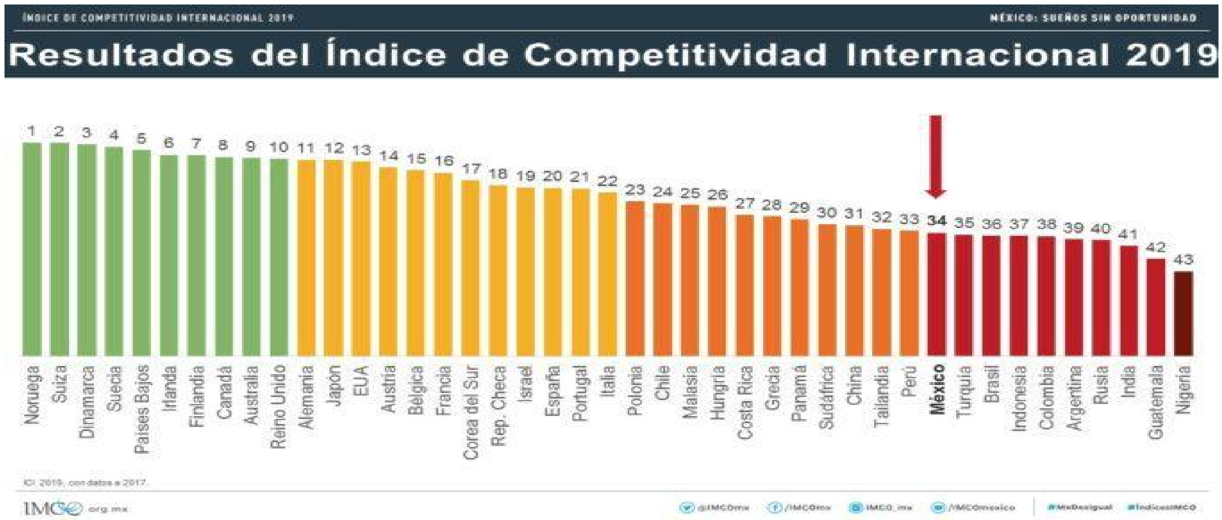

Fig. 2 Global Competitiveness Report 2019

Mexico was the second biggest economy in the Latin America region, but this is insufficient to advance Mexico's competitive advantages (Schwab, 2019). Thus, Mexico requires further efforts to accomplish the competitiveness that developed countries have reached. The GCR suggests that Mexico has well-defined areas of opportunity to improve its performance. Education, security, digital skills, critical thinking, transparency, inflation, infrastructure, life expectancy are among the areas of opportunity.

At the national level, the Mexican Institute of Competitiveness (MIC), a public policy research center, is the entity in charge of measuring the competitiveness performance within the Mexican states. Consequently, according to MIC, the GCR index unravels the inequalities among Mexican states. Mexico has 32 states in its territory, but the MIC's index reveals that only five states concentrate the best practices in competitiveness while 16 states do not even appear among the top three in the different categories such as innovation, patents, international relationships, finances, market, government, politic system, society, human rights, and environment (MIC, 2020).

3.2 Research & development. In the period from 1996 to 2018, Mexico's expenses in research and development have been on average 0.38 % of GDP (see fig. 3), which is below the average of the Latin America region, 0.71 % of GDP, and even further of the average, 2.74 % of GDP, in the North America region (World Bank, 2020).

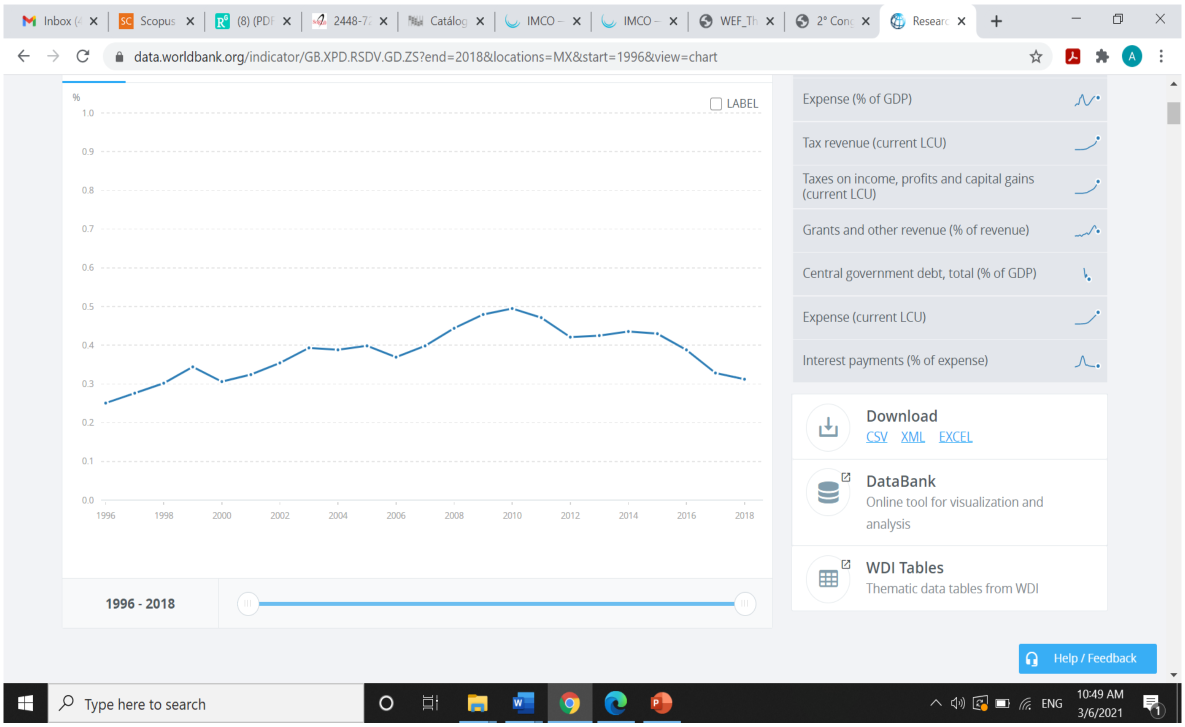

Fig. 3 R&D percentage of GDP, Mexico 1996 – 2018

Mexico relies on a few body entities for its R&D efforts. These entities oversee Mexico's strategies to promote and increase the number of scientists, publications, patents, inventions, and innovations across Mexican territory.

3.2.1 The Mexican Office of Science and Technology (CONACYT) is the entity in charge of promoting scientific and technological activities, setting government policies for these matters, and granting scholarships for researchers and graduate students.

3.2.2 The Mexican Institute of Industrial Property (IMPI) is the patent and trademark administration body in Mexico.

3.2.3 The Mexican Institute of Petroleum (IMP) is a public research organization dedicated to developing technical solutions, conduct basic and applied research, and provide specialized training to Pemex, the state-owned government-granted monopoly in Mexico's petroleum industry.

3.2.4 The Secretary of Defense, through its R&D center, generates scientific research, technological development, and innovation projects in the areas of military sciences, engineering, and biomedical.

3.3 Universities. Mexico has a network of public and private universities spread across its territory. However, the number of universities that participate in patent activities is limited. On the other hand, universities are among the main patent generators along with the Mexican Institute of Petroleum.

3.3.1 Autonomous National University of Mexico (UNAM) is the largest public research university in Mexico. It ranks highly in regional (7o in Latin America) and world rankings (141st) based on its research and innovation activities.

3.3.2. The National Polytechnic Institute of Mexico (IPN) is the second-largest public research university in Mexico and was conceived to promote the development of industrialization in Mexico. Also, IPN promotes alternatives among the Mexican population to pursue higher education.

3.3.3 Monterrey Institute of Technology and Higher Education (ITESM) is the largest private university based in Monterrey, Mexico. ITESM has a vast network of campuses across Mexico and has formed alliances with universities in the US, Canada, Latin America, and Europe.

IV. PATENTS IN MEXICO

Patents are a good indicator to measure technological change (Basberg, 1987). The global competitive index in its pillar 12: innovation capabilities evaluate patent applications (GCI, 2020). As mentioned earlier, the entity in charge of granted patents in Mexico is the IMPI. In 1994, Mexico signed NAFTA, but its effect in the number of patent applications and the number of patents granted was seen until early 2000s (see fig 4).

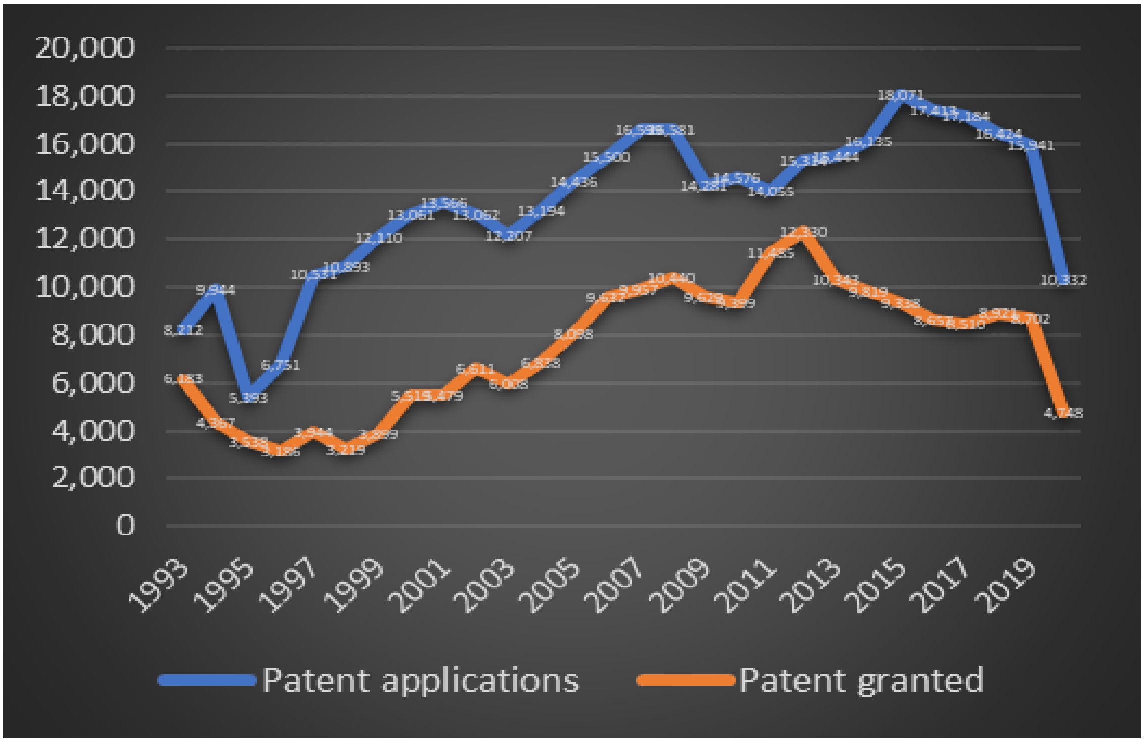

Fig. 4 Comparison between patent application and patent granted.

As can be observed, the trend of both patent applications and the patents granted is going down (see fig. 4). The tendency supports the failure of the public policies in developing an incremental number of the number of patents in Mexico over the years. Fig. 5 shows the number of patents in Mexico by states from 2018 to 2020. The map shows the inequality among Mexican states as patent generators. Five Mexican states generate almost 60 % of the total of patents granted (Mexico City 21.9 %, Jalisco 15.5 %, Puebla 6.6 %, Nuevo León 6.3 %, and State of México 5.7 %). Another interesting finding is that 16 out of 32 Mexican states (San Luis Potosí, Yucatán, Michoacán, Campeche, Chiapas, Oaxaca, Tabasco, Durango, Aguascalientes, Quintana Roo, Baja California Sur, Colima, Tlaxcala, Nayarit, Guerrero, and Zacatecas) all together account for only 10 % of the total of patents granted in the same period.

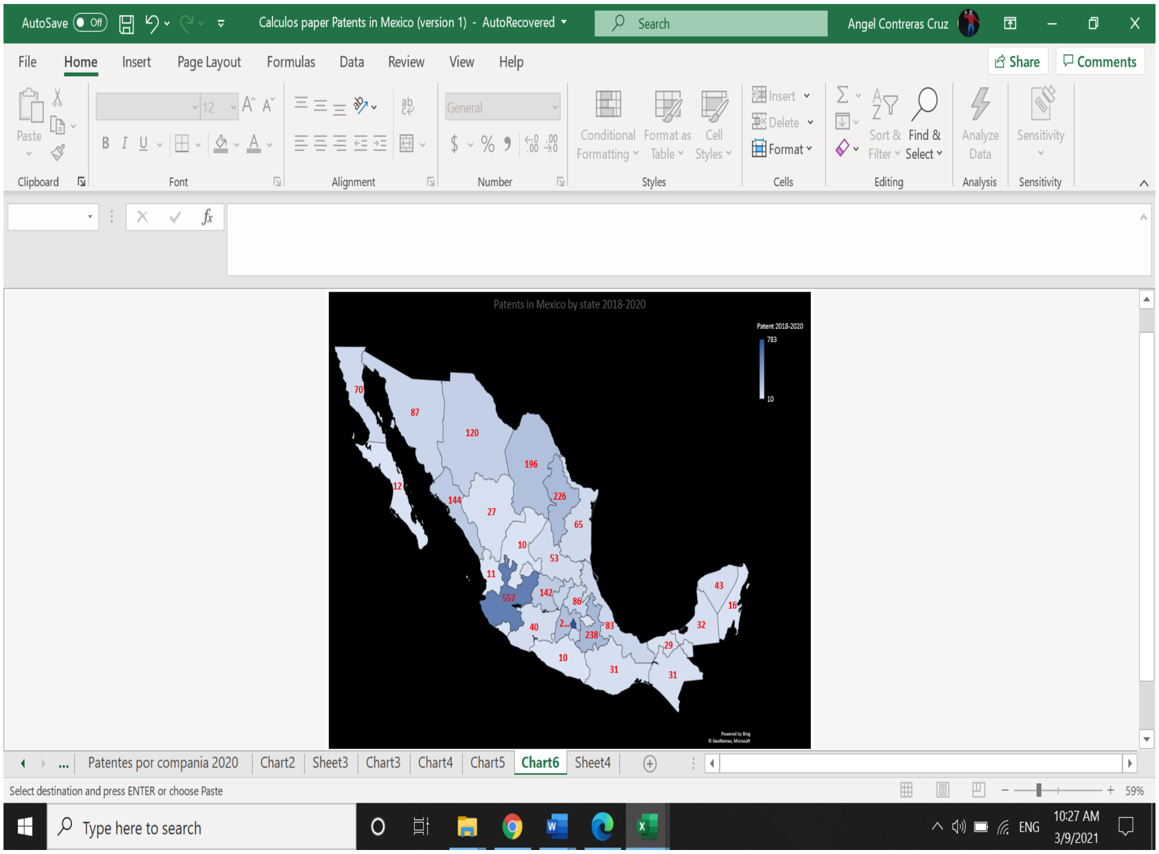

Fig. 5 Patent map in Mexican states 2018-2020

IMPI awards patents in different categories such as country, company, or nationality. Historically, the United States (188, 635 patents up to 2020) has been the main generator of patents in Mexico (see fig 6). By itself, the United State generated on average 20 % more patents than the rest of the countries that register patents in Mexico.

Germany is the second patent generator in Mexico. Over time, Germany has generated 10,000 more patents than Mexico. This has two explanations, the United States has a strong presence of its industry in Mexico (Intel, Microsoft, Colgate, MIT, Halliburton, Ford, Pfizer, Coca Cola and so on) and Germany has a strong presence through its auto industry with companies such as Volkswagen, Audi, BMW, and Mercedes Benz.

After the US and Germany, Mexico ranks third in the list of patent generators. The lack of patent generation in Mexico is reflected in the main patent holders in Mexico by the Country-of-Origin report (IMPI, 2020). The main generators of patents in Mexico are universities through their R&D departments. UNAM and IPN are the top generators of patents (21 patents granted in 2020) follow by another university, Universidad Autónoma De Nuevo León with 17 patents. After that, two R&D centers complete the list of the main patent contributors, Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco and Instituto Mexicano Del Petróleo, with seven patents each (IMPI, 2020).

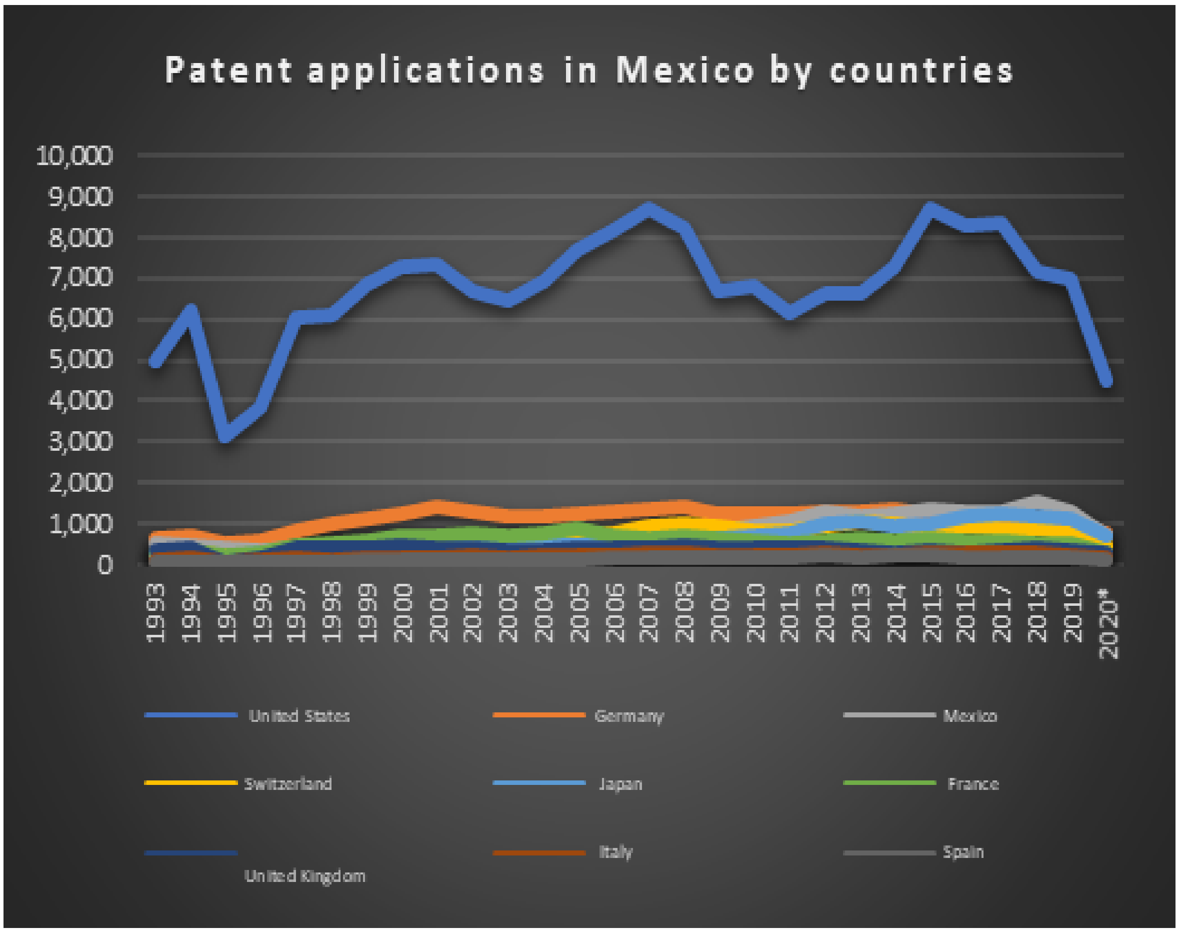

Fig. 6 Patent applications in Mexico by countries 1993-2020

Lastly, figure 7 shows the number of patents by main patent holders in Mexico by country of origin (IMPI, 2020). The top ten organizations account for up to 30% of the total number of patents granted in Mexico and includes the follow:

- Ford (US) 116 patents
- Nippon Steel Corporation (Japan) 64 patents

- Nissan Motors (Japan) 57 patents
- Halliburton Energy Services (US) 50 patents
- Nestle (Switzerland) 46 patents
- Unilever (Netherlands) 45 patents
- Colgate-Palmolive (US) 43 patents,
- Philip Morris Products (Switzerland) 43 patents,
- La Roche (Switzerland) 39 patents
- JFE Steel Corporation (Japan) 37 patents, and
- Microsoft Technology Licensing (US) 33 patents.

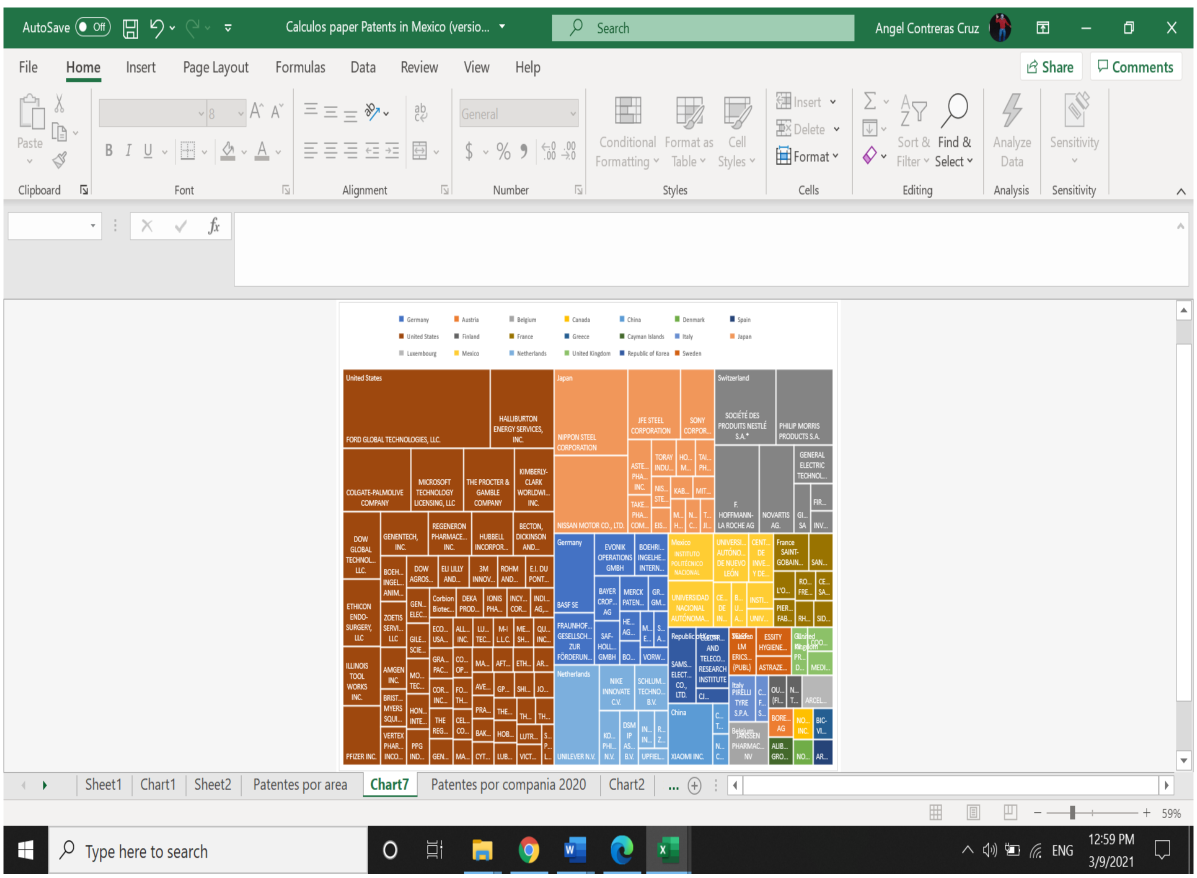

Fig. 7 Number of patents by main patent holders in Mexico by country of origin

V. METHODOLOGY

This section covers the methodological part of the paper. For this study, secondary data was retrieved from IMPI. This data encompasses different aspects such as patent applications by countries, main patent holders in Mexico, patents of Mexicans by state, and so on. The data goes from 1993 to 2020. A factor analysis was performed to analyze the data retrieved from IMPI. The software used to process the data was SPSS version 21. Table 2 shows the description of Mexico's main competitive advantage classified as patents granted.

Table 2. Description of variables included in the model.

Variable	Name
V_1	Consumer Goods
V_2	Chemistry and Metallurgy
V_3	Fixed Constructions
V_4	Physics
V_5	Industrial Techniques
V_6	Textile and Paper
V_7	Mechanics - Lighting Heating - Armament Blasting
V_8	Electricity

Factor analysis has been used to explain the relationship between variables and the resulted values can create a model with a single or few common factor (s) (Olkin & Sampson, 2001). Factor analysis can be used in two contexts (1) to confirm or negate a hypothesis and (2) to discover a structure or as an exploratory model (Olkin & Sampson, 2001). In this paper, context number 2 was used as an approach. Table 3 shows the results of the factor analysis performed.

Table 3. Factor Analysis Summary, KMO =.645 (*); TVE= 83.05% (**); p< .001(***)

Variable	Component 1	Component 2
Consumer Goods	**.954**	.030
Industrial techniques	**.780**	.440
Chemistry and metallurgy	-.121	**.922**
Textile and paper	-.022	**.933**
Constructions	**.851**	-.273
Mechanics and lightning	.341	**.801**
Physics	**.904**	.187
Electricity	.612	**.641**

* KMO: Kaiser-Meyer-Olkin Measure of Sampling Adequacy
** TVE: Total Variance Explained
*** p: significance
Extraction Method: Principal Component Analysis.

VI. RESULTS

Despite Mexico's effort to be more competitive in a global economy, the results show that it is far away from developed nations. The technological innovation sector, according to the number of patents obtained from Mexico, is inexistent. More of the technological innovation inputs in Mexico are created by foreign companies or countries.

I suggest that Mexico's competitive advantage can be evaluated by analyzing the different categories by technological field. The factor analysis suggests that there are two main components where component 1 includes consumer goods, industrial techniques, constructions, and physics are main Mexico' strength (4,382 patents) while component 2 includes chemistry and metallurgy, textile and paper, mechanics and lightning, and electricity are an area of opportunity to Mexico to develop policies to increase the number of patents in this respect (2,157 patents). Component 1 doubles the number of patents of component 2. Also, component 1, which includes four variables has a strong correlation and explains Mexico's strong competitive advantage by 52.41 % (percentage of variance). Finally, component 2 explains the situation by 30.46% (percentage of variance).

VII. CONCLUTION

New policies need to be designed to increase the number of patents in Mexico. Some recommendations can be made after the assessment of Mexico's current situation.

1) Increase over time the investment of GDP into R&D to generate more infrastructure and human resources and increase the number of patents.
2) Promote higher education among the Mexican population providing scholarships for those who are interested.
3) Promote policy adoption from the leading patent generator countries. It will be necessary to conduct a study to identify policies that can be replicated in the Mexican context.
4) Reduce the gap of patent applications and patents granted between Mexican states. It is important to increase the number of patents in more of fifty percent of Mexican states.
5) Involved more universities, R&D centers, and SM companies to promote patent generation. Even though Mexico has implemented new policies related to patenting, not

all universities and organizations have access to these policies. The lack of resources makes this situation even worse.

FUTURE RESEARCH AND LIMITATIONS

Available public data from the Mexican Institute of Intellectual Property is restrained. To expand the scope of this paper, it is recommended to use a broader data set to obtain more detailed results.

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In 2019, he joined the Ph.D. program in Engineering in Technology Management (ETM) at Portland State University. Since the year 2020, he is a Graduate Assistant in the ETM Department. He has collaborated with Dr. Tugrul Daim as a Teaching Assistant in the following courses, Decision Making, Engineering in Technology Management, Technology Assessment and Acquisition, and Technology Transfer. He participated as a co-author in the article "Unraveling the Dynamics of Immigrant Engineers` Full-utilization in Australia," which is under the revision of IEEE Transactions on Engineering Management. His research interests include high-skilled migration in the US, patent analysis, technology forecasting, and technology transfer.