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Assessing Innovation Activity in Mexico and South Korea: An Econometric Approach

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***Abstract*—**This article analyzes innovation activity in Mexico and South Korea. It develops an econometric model to test for structural breaks in the number of patent applications filed by residents and nonresidents in these countries during the period of 1965 to 2012. These changes may suggest that firms' innovative capabilities have changed because of implementing different science, technology and innovation (STI) policies in Mexico and South Korea. Two important features characterize this research from others already developed by these authors. First, the theoretical research framework in this research is the debate between the assimilation view of growth and the accumulation view of growth. This characteristic suggests that trade liberalization should be accompanied by an adequate STI policy to boost competitiveness among indigenous firms. Second, the analysis in this research stresses the importance of key actors (e.g. governments) to successfully develop innovation capabilities among indigenous firms. Therefore, the question conducting this research is how STI policies in Mexico and South Korea contributed to develop firms' innovation capabilities in these countries during last decades? The results from this research suggests that STI policy in South Korea was more suitable to boost innovation firms to compete in markets. Data to develop this research was released by the World Intellectual Property Organization (WIPO).

***Keywords*—**Econometric methods, innovation, Mexico, South Korea, STI Policy.

I. Introduction

THIS paper analyzes the possibility of finding structural breaks in the series of patent applications of residents and nonresidents in Mexico and South Korea. In this sense, econometric methods are applied to test for structural breaks. In these countries, science, technology and innovation (STI) policy may support the development of innovation capabilities among firms. In the case of Mexico, it is argued that the development of science and technology does not correspond to support the advancement of an innovative and competitive economy. In contrast, in the case of South Korea, STI policy has been more supportive to develop innovative capabilities among firms.

In addition to this introduction, this paper is organized into four sections. Section two contains the literature review in relation to STI policy implemented in Mexico and South Korea. Section three discusses the econometric model used in this research to analyze the possibility of finding structural breaks in patent application series in Mexico and South Korea. Section four presents the results achieved in this research. Finally, Section five contains some conclusions from this research.

II. Literature Review

Since the late 20th century, there has been great competition among countries and companies to achieve higher levels of innovation in production processes. They invest part of their revenue in R&D which allows them to increase their productivity and production capacity, and by doing so the industries play a greater role in markets.

Through innovation, it is possible to create scientific and technological knowledge that is reflected in economic improvements, as well as in a growing number of patents that allow industries to have competitive advantage by offering new goods and services in the markets. Many authors study the relevance of innovation in different countries in order to achieve economic advancement [1]-[7]. In this regard, this research analyzes innovation activity in Mexico and South Korea from the perspective of patent applications.

A. The Asian Miracle

East Asian economies, especially Taiwan, Hong Kong, Singapore and South Korea during the 1950s and 1960s, had production processes that corresponded to those of underdeveloped countries, which kept the majority of their population at low levels production and income. In order to overcome this, throughout different periods they each began with policies to boost R&D which contributed to the transformation of processes and goods, as well as increasing their participation in markets.

Since the late 20th century, Taiwan, Hong Kong, Singapore and South Korea have had industrial structures based on innovation which allows them to consolidate the creation of science and technology that favors learning, innovation, and the development of new products. These are offered in markets and contribute to the growth of the economy, as well as the growth of family income and revenue toward R&D [8], [9].

Some econometric analyses detect the differences in scientific and technological knowledge in East Asian and Latin American countries [1]. These studies found that the countries of East Asia, such as Taiwan, Hong Kong and South Korea, focused their science and technology policies on technological knowledge which enabled them to boost the economy and

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generate patents that help to solve the problems of the industry and promote economic growth [1]. In contrast, in Latin America, science and technology policies were focused on scientific knowledge, especially on the publication of scholarly and scientific articles consisting of research that was irrelevant to the problems of the national industry, and therefore resulting in low economic growth rates in the region and a modest number of patents registered across all sectors of these economies [1].

Certainly, scientific articles and patents contribute to the transformation of society as well as the transformation of industrial processes. However, in East Asia countries, the policies to boost science and technology concentrated on technological knowledge, meaning that each year they increasingly invested more resources in R&D and focused on the creation of science and technology related to solving problems of the industry. In this way, companies improved their performance, as well as their levels of competitiveness through innovations in processes and goods, reaching higher levels of production and differentiation of their products in markets.

In this way, science and technology policies contributed to the economic growth and the increase of the number of patents of their companies in both Taiwan and South Korea, which in contrast to Mexico and Brazil do not possess many patents and have lower economic growth rates than many East Asian economies [1], [10], [11]. Especially, in the case of South Korea, the increasing participation of the private sector in R&D stands out, reaching up to 70% of the total national R&D since the 1990s, in contrast to less than 30% before the 1980s. In Latin America, it is still understood that the state should make the greatest contribution to R&D with the composition in reverse: 30% for private initiatives and 70% for the state.

According to data from the World Bank, in triadic patent families, that is, patents registered at the European Union, the United States of America, and Japan, the world's most important markets in the economy and trade, South Korea managed to register 3,154 patents in 2013 while Mexico only filed 17 patents, showing the difference in science and technology policies in East Asia and Latin America [12]. In the same year of 2013 South Korea had 12.8 researchers per thousand employees and Mexico had only 0.8 researchers per thousand employees [13], showing the lag between the two nations in terms of innovation. Innovation stimulates the growth of the economy and the birth of new companies that contribute to the increase of wealth and resources for R&D, revitalizing the advances of science and technology that have an impact on processes and offered goods, as well as the demands of various markets that make up the international economy [14], [15].

B. Research and Development (R&D) and Absorptive Capacity

R&D is carried out in all countries, except that some invest more financial and human resources in this activity. Nations that channel more resources to the creation of science and technology show higher levels of development in their society, as well as reduction of levels of poverty in the population and acquire a larger presence at the international level for the development of patents, much like the differences that are occurring between South Korea and Mexico in the generation of scientific and technological knowledge. This influences the process transformations of its companies which contributes to competitiveness and the design of new goods and services which are offered in the markets [8], [9].

When faced with the constant need to create and improve processes, goods, and services, countries and companies develop through their science and technology policies and the implementation of innovation systems that contribute to generate conditions of linkage with other nations that strengthen their competitiveness and higher levels of sophistication in the processes of innovation world-wide [2], [16].

As mentioned, countries that invest more resources in the creation of science and technology have more developed economies and companies [3], [9], [15], [17]. In the year 2013, the United States invested 2.7 percent of Gross Domestic Product (GDP) in R&D, Japan 3.5 percent of GDP, Germany 2.8 percent of GDP, South Korea 4.1 percent of GDP, Brazil 1.2 percent of GDP, and Mexico 0.5 percent of GDP [12]. In the aforementioned countries, the smallest amounts devoted to boost R&D are from Brazil and Mexico, which are countries considered to be in the process of industrialization and need to increase the amounts allocated to boost scientific and technological knowledge if they want to get closer to the creation and design of cutting-edge technology in an increasingly competitive world for the scientific and technological knowledge that is created in countries with higher investments in R&D.

When innovation is a factor of economic growth and the wealth of society, it is important to emphasize that state-driven policies of science and technology can create scientific knowledge without having impact on technological knowledge since they are not related to the research of industrial problems. So, it should be ensured that the amount of investment allocated to R&D is capitalized to its maximum, as well as scientific and technological knowledge so that it allows countries in the process of industrialization such as Mexico to learn and innovate as the industrialized nations of East Asia have done so. Technological knowledge is mainly determined by firms' efforts in R&D [1], [18] to maintain innovations constantly in process and commercialized goods in markets, driving economic growth and structural change in productive structure [5], based on the permanent innovation of processes that have an impact on science and technology.

C. Foreign Direct Investment (FDI) and Technology Spillovers

As mentioned before, investment in R&D contributes to the process transformation as well as goods and services that are exchanged in the markets which is why all countries have policies for the creation and development of science and technology. This allows having systems of innovation that links them with other nations to continue to advance and revitalize scientific and technological knowledge which helps solve societal and industrial problems.

The industries being in constant transformation, contribute to generate a greater link between countries for the exchange of goods and services as well as to mobilize capital through foreign direct investment (FDI), which they do so in diverse markets and thereby also boost technological progress.

FDI is a process that companies take to expand their production process in different countries that allows them to grow their markets. With FDI new knowledge is transferred to the markets and it favors the development of improved cutting-edge infrastructure which catalyzes scientific and technological knowledge. FDI stimulates innovation and contributes to the growth of knowledge as well as technology [3], [4], [19].

In order to attract more FDI that contributes to boost innovation in scientific and technological knowledge, countries need to establish competitive structures related to highly trained human resources and communication infrastructure, enabling companies to take capital and develop leading-edge processes in the markets in which they are established and also create the conditions that allow them to face world competition to gain new places in the markets [19]. Thus, drawing in larger amounts of FDI requires institutions that foster science and technology policies which will allow them to have solid foundations for attracting investments from companies with state-of-the-art technological processes that will lead to the emergence of more companies as well as innovations in processes and goods, pushing the growth and modernity of the economy [4], [19].

In South Korea, the industry was able to achieve modernization because it received FDI from various countries which enabled Korean entrepreneurs and employees to receive training and technical assistance in the 1950s, 1960s, and 1970s. In the same way, the Korean government and its institutions were linked to the companies in order to generate conditions that allowed them to achieve the process of learning the industrial knowledge that was established in their territory. In the eighties and nineties, the products of the automotive and electronics industries, among others that were developed and modernized with the arrival of FDI reflected learning and innovation [6], [18].

In the case of Mexico, FDI was also drawn in, but it did not have the same learning and innovation processes as those achieved in South Korea. In this country, science and technology activities were focused on scientific knowledge without much relevance to industrial problems, thus affecting the modernity of processes as well as the learning and the innovation of cutting-edge technologies [1], [11], [19].

D.Innovation Activity in Mexico and South Korea

The innovation processes that countries had achieved are related to the capacity to invest in R&D as well as the conditions of structures and infrastructure that encourage the arrival of state-of-the-art FDI. In South Korea we mentioned that science and technology related policies were focused on technological development with which companies acquired knowledge that allowed them to innovate and create patents in processes as well as enhanced products that were launched in the market [1], [20].

With the work done in designing science and technology policies that allowed Korean companies to compete by creating patents through innovations and new products, competition began on the basis of new product development and R&D which invigorates the work of production systems with a sustained base on innovation that helps achieve and maintain leadership in electronics and automotive industries as Samsung and Hyundai had done among other companies such as related companies of the steel industry, ship and semiconductor production [7].

Like those of South Korea, companies in Mexico also make efforts to compete in markets with product innovations, but the amount invested in R&D is low compared to that of Korea resulting in fewer patents in Mexico (in 1990 it had 7 patents and in 2013 only 17 patents) than Korea (in 1990 Korea had 68 patents and by 2013 it had 3,154 patents) [11]-[13], [21]. In the same way, there are relevant efforts that stimulate the universities' opportunities to provide each day, the increase of qualified population that expanded competition and innovation among companies and also established institutions such as the Ministry of Education, Science and Technology, the Ministry of Science in March 2013, ICT, and Future Planning among others, which were created to allow Korean industries to have policies that integrate the government, industries, and universities [22].

In Mexico, the implementation of policies was not comprehensive. In 1970 the National Council of Science and Technology (CONACYT) was created which is the impetus for research and development in science and technology, but with less favorable results in comparison to what South Korea has achieved in science and technology innovation and its impacts on the industry. Since the creation of CONACYT, the National System of Researchers (SNI) has been available to improve, stimulate, and link scientific and technological activity since 1984, enabling educational and technological activities to be more closely associated with socioeconomic development and the emergence of new nuclei of research in the productive sectors [11]. R&D investment policies as well as the amount allocated to education are favorable to society and its productive sectors as both contribute to process innovations and goods and services that a society produces and consumes to be competitive on the world scale. According to the previously mentioned data regarding the amount of R&D investments, the number of researchers per thousand employees, and the number of patents created, this shows Mexico in an uncompetitive position in comparison to South Korea which corresponds to the low level of development of science and technology and the innovation of processes and goods that are commercialized in markets [11], [21].

Therefore, in Mexico, financial and human resources that have been channeled in favor of the promotion of science and technology hold limitations that affect national capacity and the generation of innovative processes in science and technology differently because these resources have been insufficient compared to the needs of the Mexican industry, which affects the creation of patents that contribute to the increase of wealth relevant to research and development. This demonstrates the need to create and develop strategic areas that allow the Mexican industry to maintain a dynamic process and innovation of goods, as well as create synergy among the government, industries, and universities that will result in more employees dedicated to science and technology and patents with exclusive rights that allow the positioning of products of the Mexican industry.

According to what we have mentioned in relation to R&D investment, the number of patents that have been registered in the markets of Europe, the United States, and Japan and the number of people dedicated to the development of science and technology, Mexico, unlike South Korea, is dependent on the advances of science and technology generated in other countries.

III. THE MODEL

The model was estimated using values of the growth rates of the number of patent applications filed by residents and nonresidents in Mexico and South Korea. Data of the number of patent applications of residents and nonresidents in this research was released by the World Intellectual Property Organization (WIPO).

The analysis of structural breaks in patent application series through the Bayesian Information Criterion (BIC) has been applied in other studies [20], [23]. In the analysis of time series, it is possible to find structural changes such as in the case of patent applications filed by residents and nonresidents [20], [23] in Mexico and South Korea might be the result of their own science, technology and innovation (STI) policy adopted in these countries (e.g. new dispositions in terms of intellectual property). Structural change or structural instability has commonly interpreted as a change in the regression parameters [24].

Specifically, the presence of a structural change can be explained and tested through a dynamic autoregressive model of order one *AR(1)* [25]. In this case, it is necessary to determine its existence and its temporary location in a regression model. Accordingly, this question can be analyzed in a simple dynamic model, the autoregressive model first order, *AR(1)* [25]:

$$Y_t = \alpha + \rho Y_{t-1} + e_t \ldots \qquad (1)$$

$$\sum_{t-1}^{n} \frac{e_t^2}{n-k} = \sigma^2 \ldots \qquad (2)$$

Y_t in (1) represents a series of time and Y_{t-1} is the same series with a lag period. The error term e_t complies with the assumption of no serially correlated. [25]. Equation (2) estimates the variance. In this equation, the numerator is the sum of squared errors, and the denominator are the degrees of freedom [26]. When one or several parameters in the sample of this model change, it can be said that a structural break has occurred [25]. In the analysis of time series, then it is possible to find structural changes such as the series of patent applications filed by residents and nonresidents [20], [23] in Mexico and South Korea may result from new regulatory changes in their science, technology and innovation policy, intellectual property regimes, and so forth.

However, structural breaks in this study were endogenously computed using Bai and Perron's methodology [27], [28] applying a different criterion than in other studies [20], [23]. This approach allows testing for structural breaks in the series of patent applications of residents and nonresidents in Mexico and South Korea.

The following variables were defined in this model in order to test for structural breaks in the number of patent applications of residents and nonresidents in Mexico and South Korea (as shown in Table I).

TABLE I
VARIABLES DEFINITION

Variable	*Definition*
PARMEX	Number of patent applications of residents in Mexico
PANRMEX	Number of patent applications of nonresidents in Mexico
PARROK	Number of patent applications of residents in South Korea
PANRROK	Number of patent applications of nonresidents in South Korea

An important feature in the analysis of this research is that innovation in South Korea is primarily driven by the private sector that dominate the private spending in R&D in this country (e.g. Samsung, Hyundai, POSCO and LG) [20].

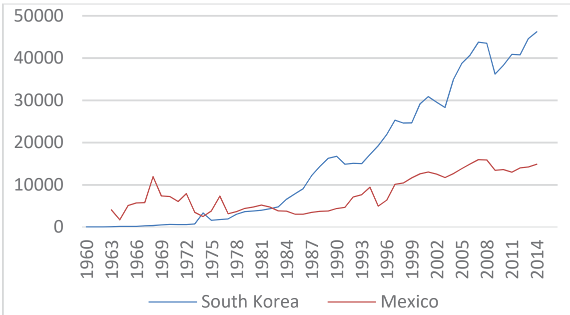

Fig. 1 Patent Applications, 1960-2014 (Non Residents)

Fig. 1 shows the number of patent applications of nonresidents in Mexico and South Korea from 1960 to 2014. In both countries, the number of patent applications of nonresidents has increased since the 1980s because of some changes observed in their intellectual property regimes (v.g. allowing universities patenting, removing restrictions on licensing, uniformizing patent policies, and so forth). The result has been a more accurate STI policy to successfully transferring patentable knowledge and technology to industry.

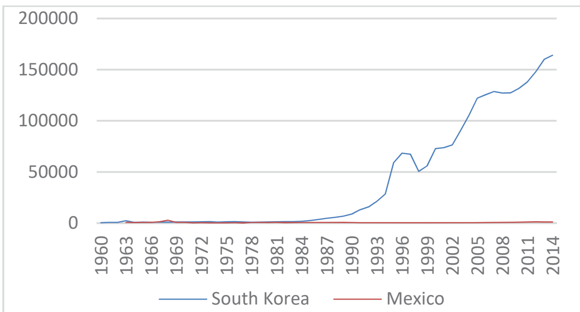

Fig. 2 Patent Applications, 1960-2014 (Residents)

Fig. 2 shows the number of patents applications of residents in Mexico and South Korea from 1960 to 2014. As in Fig. 1, the number of patent applications of residents increases since 1980s and 1990s. However, in the case of South Korea, the number of patent applications increases dramatically during these decades because of a more accurate STI policy implemented in this country, showing more clearly these trends derived from the new dispositions observed in the intellectual property regimes in this country.

IV. Results

This model was estimated using RATS 6.0. From a general perspective, STI policies adopted in Mexico and South Korea are important to explain patenting activity among residents and nonresidents in these countries.

In the case of Mexico, structural breaks are observed in 1973 and 1980 in the series of patent applications of both residents and nonresidents. These results confirm other studies previously developed in the case of Mexico [23]. In the case of this country, there is not structural breaks after 1980. These results may suggest that the intellectual property regime in Mexico has only been adapting to some changes experimented in the intellectual property regimes in many countries in the 1970s, and thus there is not a supporting STI policy to develop innovation capabilities among firms in this country.

TABLE II
Results

Variable	*Year of Break*	*F-Statistics*
PARMEX	1973	2.60
	1980	2.65
PANRMEX	1973	3.26
	1980	3.78
PARROK	1978	9.41*
	1996	6.37**
PANRROK	1976	6.70*

In the case of South Korea, structural breaks are observed in 1978 and 1996 in the series of patent applications of residents, and in 1976 in the series of patent applications of nonresidents (Table II). These results confirm other studies previously developed in the case of South Korea [20]. However, these results may imply a successful STI policy allowing to develop innovations. Therefore, the development of innovation capabilities among firms in South Korea has been more important than in Mexico. In the case of this country, STI policy has been highly successful to enhance patent applications by residents during this period, reflecting a more entrepreneurial attitude among inventors [20].

V. Conclusions

The results achieved in this research suggests that STI policy adopted in South Korea has been more successful to boost innovation capabilities than in Mexico. In the case of South Korea, this policy has favored learning, innovation, and thus patenting and the development of new products by firms to become more competitive in markets. In contrast, in the case of Mexico, the development of science knowledge has been more motivated to the publication of scholarly and scientific articles irrelevant to problems solving of its national industry. The consequence is that economic development and income levels have dramatically improved in South Korea, while income levels in Mexico has not improved.

In this research, econometric methods were used to endogenously test for structural breaks in the series of patent applications filed by residents and nonresidents that reflect the possibility of implementing alternative STI policies to support the development of innovation capabilities in these countries. Econometric methods in this research contribute to demonstrate how STI policy has been more successful to achieve this objective in this case of South Korea.

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