Volume 49, Number 195, October-December 2018

The Effect of Innovation on Development and Growth in Mexico: An Approach Using Patents

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Date received: December 21, 2017. Date accepted: May 20, 2018.

Abstract

This paper introduces an empirical model drawing on data generated over a decade of analysis, aiming to explain the impact of intellectual property by using patent records as an indicator. The model moreover correlates patenting with economic development and growth in Mexico. The pattern that emerges is a positive tie between greater investment in research and development (R+D) on the one hand, and economic development and growth on the other, manifest in the rising volume of national patent applications. The development and implementation of public policies designed to augment intellectual capital and innovation could benefit an emerging economy like that of Mexico in countless ways.

Keywords: Patents; economic development; technological change; R+D; linear regression analysis.

1. INTRODUCTION

The relationship between patents and economic growth in national economies is a topic that has been studied for decades, suggesting that the literature pretty much falls into one of two categories: *1*) studies that do indeed find a direct link between patents and economic growth; and *2*) research that determines that the relationship between the two variables is indirect (Campo, 2012). Grossman and Helpman (1991) asserted that the trend in the global economy is one in which technology innovations have become the decisive factor behind economic growth and well-being. In open and interdependent economies, the rapid communication furnished by new technologies and the close contact among innovative companies facilitates the invention process for knowledge to spread, leading to an increase in investment in research and development (R+D) in these countries.

Over time, thought has evolved to contend that production processes were fundamental to economic development via innovation in each era. Nowadays, this has come to be known as the knowledge economy. In recent years, innovation and technological change gave gained popularity in economic analysis and policy decision-making in developed countries. Schumpeter (2009) held that technological innovation was the essential motor powering economic growth.

A range of factors can lead an economy to growth and economic development. Although innovation economics is not a standalone concept, it is indeed possible to assert that it is a branch of economics whose purpose is to explore and understand the different dimensions of the phenomenon of innovation from a multidisciplinary standpoint (Corona, 2011). Technology innovations are a key aspect to boosting the productivity of factors in the economies that at present have climbed to the highest rungs of development and industrialization.

In this sense, the nature of innovation is rooted in human creativity. It is through innovation that it is possible to create new market patterns and systems and generate new knowledge, with a close relationship between growth and innovation such that development in many countries is in large part reliant on their ability to produce and incorporate these technologies into productive transformation.

Innovations are endowed with human intellectual capital, which can be understood as an intangible value associated with a combination of human resources and latent intangible assets (Pulido San Román, 2008).

Innovation economics is by nature multidisciplinary, as it is driven by the nature of innovation, which is to say, it is as complex as the suite of disciplines involved, as varied as: engineering, sociology, social and individual psychology, theory of learning, management, territorial studies, bioeconomics, biotechnology, and, within the sphere of the economic sciences: economic history, evolutionary economics, new microeconomics, cognitive economics, institutional economics, and economic psychology.

The purpose of this paper is to demonstrate whether there is a relationship between innovation and economic development in the time period running between 1998 and 2009, using a number of patents as an indicator, as well as to describe the overall outlook for patent behavior in Mexico.

The idea is to furnish empirical evidence that technological progress, measured by the indicator of inventive activity in the form of patents, is a relevant factor that influences economic growth and development. To do so, an economic policy is needed that creates enough incentive for the private sector, in conjunction with governmental agencies, to invest in R+D.

2. BACKGROUND

Innovations are endowed with human intellectual capital. These “intangible assets” have an economic and a non-economic value, and, as such, are oft protected by diverse legal regimes granting intellectual property rights. Patents are the most common means of obtaining the right to new inventions resulting from scientific research. The rights granted to inventors through patent protections are regularly transferred from research institutions to the productive sector via licenses or sale.

This “technology transfer” can generate countless economic benefits. For example, the proper titleholder to a patented invention can produce goods that have greater commercial value than the competition’s products, and also attain a more enviable market position. Accordingly, policies that invest in research and promote technology transfer play an essential role in economic growth (Sánchez and Ríos, 2011). As a nation, Mexico is endowed with substantial human capital, but in the past, the intangible assets created by Mexican researchers were not effectively transferred to the productive sector. The transformation of these inventions into innovations could have a significant influence on the country’s future growth and economic development.

It is important to bear in mind what is understood by innovation, pursuant to the Oslo Manual: “the introduction of a new or significantly improved product (good or service), process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations.” Innovation may have one or more components, and can be categorized as a result. These are: technological, applied research, social improvements, improved administrative process, among others, meaning that there are different ways to protect innovation via legal pathways. According to the Oslo Manual, the innovation generated at organizations fits into one of four modes: *1*) product innovation; *2*) process innovation; *3*) marketing innovation; *4*) organizational innovation.

There are several reasons justifying the use of patents as an indicator of inventiveness. Griliches (1990) argued that a "patent does represent a minimum quantum of invention that has passed both the scrutiny of the patent office as to its novelty and the test of the investment of effort and resources by the inventor and his organization into the development of the product or indicating thereby the presence of a non-negligible expectation as to its ultimate utility and marketability.” Contemporary economists continue to use patents as an indicator of inventive activity. Besides their theoretical relevance, patents offer various advantages when it comes to economic analysis. For example, they contain detailed technical information about new and useful inventions. Information about patents is available freely and publicly.

There are also limitations surrounding the use of patents as economic indicators. For example, not all technological improvements are patented, and it is particularly difficult to locate information on commercial practices. Moreover, other problems include the fact that a review of patent documents is complicated as a result of comparing one format with another, and the fact that patent language tends to be unclear to the non-specialized reader (Diessler, 2010). Other disadvantages related to using patents as indicators include frequently-changing intellectual property laws and commercial practices, as well as the inability to easily distinguish between "strong" and "weak" patents (Sánchez *et al.,* 2018).

In spite of these limitations, patent applications furnish a good deal of information that serves as a useful input for economic analyses. For example, the scope of claims on an individual patent is by nature unique, in terms of both the wealth of the information contained in it as well as the breadth of the coverage of each claim.

Where the connection between innovation and economic development is concerned, myriad studies have concluded that technological change is a key factor in economic growth (for example: Solow, 1957; Romer, 1987, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). Research by Abramovitz (1956) and Solow (1957) laid the groundwork for the relationship between innovation and economic growth. The author’s second work noted that technical change—the so-called “Solow residual—is a factor that does indeed impact the long-term growth rate. At this point in developing the theory, technical change was considered an exogenous driver of the model, a major limitation that could not be attributed to the decisions made by economic agents.

This limiting factor was the subject of criticism and encouraged other researchers like Romer (1986), Lucas (1988), Barro (1990), and Rebelo (1991) to offer the explanation tying the long-term growth rate to endogenous variables pertaining to the research and development sector, like knowledge accumulation, human capital, and public spending, to formulate equations that imply technical change. This wave of work would usher in the advent of endogenous growth theory and came to be known as the first-generation models of this current of economic thought. Later on, this first generation influenced the development of the second-generation Romer (1987 and 1990), Grossman and Helpman (1991), and Aghion and Howitt (1992) models.

The novelty of these models was that they included an analysis of the relationship between economic growth and research in a scenario of imperfect competition (monopoly). The rigidity of technical change as an exogenous factor was relaxed, conceptualized as that which creates new designs with the intent of improving the competitiveness of productive processes, in turn prompting an impact on economic growth that is dynamic and ongoing, with the assumption of constant returns to scale.

One of Solow's (1994) critiques of the new economic growth theory is that it only relaxes the assumptions of the neoclassical model related to technical change. One major limitation on the endogenous models, pointed out by Dutt (2003), is that they do not take into account the traits inherent to technology and the factors (institutional, cultural, and firm-level) related to technical change. In a more recent work, Jones and Romer (2010) argued that modern economic growth theory requires the interaction of ideas, population, institutions, and human capital, variables that are key to explaining income differences between countries and accelerated growth, and which are points that have not been stylized in the dynamic models.

Internationally, some studies have used patents as an indicator of innovation with a positive impact on economic growth in countries with cross-sectional data, time series, and panel data. The econometric techniques used range from least ordinary squares (LOS) to more sophisticated estimators, like time series, fixed effects (FE), random effects (RE), the semi-parametric generalized additive model (GAM), the regression ridge, the Arellano-Bond Generalized Method of Moments (GMM), and the Blundell-Bond GMM (Maskus y McDaniel, 1999; Bilbao-Osorio y Rodríguez-Pose, 2004; Ulku, 2004; Torun and Cicekci, 2007; Blind and Jungmittag, 2008; Hasan and Tucci, 2010; Sattar *et al*., 2013; Pece *et al.*, 2015; Guastella and Timpano, 2016).

In the case of Mexico, papers have found a positive relationship between patents and economic growth, using panel data with the random effects economic treatment, the Arellano-Bond GMM, and spatial econometrics approaches (Marroquín and Ríos, 2012; Ríos and Marro-quín, 2013; Torres-Preciado *et al*., 2014; Ríos and Castillo, 2015; Ríos-Flores and Ocegueda, 2017). Nevertheless, bear in mind that although research has been done into the link between economic growth and patents in Mexico and the Latin America and Caribbean region, the patent rate is lower in the region because spending on research and development is less than it is in developed economies (Naciones Unidas-Cepal, 2016). For his part, Cimoli (2005) noted that Latin American and Caribbean countries have predicated their growth and development on the generation of rents derived from sectors with abundant factors, while the industrialized economies rely on more knowledge-intensive sectors, caused by technological asymmetries and structural heterogeneity between the two groups of countries. For that reason, the impact of patents on economic growth is lower in developing countries than in developed economies, and the international empirical evidence has borne it out.

On another note altogether, Lanjouw *et al.* (1996) pointed out that measures of the reach of innovation patents are unique, both in terms of the wealth of information they contain and the breadth of their coverage. Patent documents contain details on the characteristics of individual innovations (for example, technological area or citation of related innovations) and inventors (both the per se inventor and the owner or licenser of the patent), unavailable anywhere else. Unlike information on R+D spending, which is available more for a subset of large companies, patent data is accessible for any company or person over a long time period. These characteristics make it possible to use patent data to study the efficacy of policies adapted to certain technological spheres or specific company types, the field via the profits flowing from the patent system, externalities in the knowledge generation process, and many other related phenomena.

Empirical evidence from diverse authors has led to the notion that protecting industrial property and changing policies in an economic region can bring about long-term economic growth and development. Gould and Gruben 81996) studied the role intellectual property rights have played in countries' economic growth, using cross-section data for patent protection. Later, Park and Ginarte (1997) demonstrated that patents can have a positive impact on capital accumulation, and that increases in fixed capital are related to positive economic growth.

Intellectual property expressed in patents is the most widely used form of protection as a measure of innovation, as it is a mechanism that incentivizes research, generates the appropriation of income, and has a positive impact on a country's growth and development.

3. METHODOLOGY

Following Romer (1990), the empirical analysis is grounded in an economic growth model where the main driver is the result of investment decisions made by profit-maximizing agents. The model is based on three premises:

1. Technological change, understood as an improvement in processes (knowledge) to combine inputs in production, is at the base of economic growth.
2. Technological change arises as the result of intentional actions taken by people responding to market incentives. That is why technological change is endogenous and not exogenous in the economic system.
3. Technology understood as the methods to work with raw materials is essentially different from any other economic good. Industrial designs are equivalent to incurring a fixed cost given that they are considered non-rival inputs, as once created, the cost of using them on an ongoing basis is non-existent to manufacture new goods.

Pursuant to the foregoing, the resulting equilibrium from the model cannot be underpinned by a price-taking behavior in the market structure, but rather in a context of monopolistic competition. Consequently, as the market grows, it not only has an effect on the income and welfare level, but also on the economic growth rate. That means that the more the market grows, the more research is stimulated, and it brings about faster growth.

There are three sectors in the model:

1. The research and development sector (R+D) and the existing stock of knowledge to produce new knowledge.
2. The intermediate good sector, which uses the knowledge from the research sector together with the production sacrificed by the large producers of durable goods, available for use in producing final goods at any moment.
3. The final goods sector that uses labor, human capital, and the set of durable goods producers available to produce the final product.

If we begin with the assumption that accumulated capital is considered sacrificed consumption, as it is assigned from the consumption sector to the capital goods sector to produce new designs, under a monopolistic structure, the formal product model is formulated by the following Cobb-Douglas production function:

$$Y\left(H_Y, L, x\right) = H_Y^{\alpha} L^{\beta} \sum_{i=1}^{\infty} x_i^{1-\alpha-\beta} \qquad (1)$$

Where x is the set of inputs used (durable goods or a technology level index) by the company to produce the final product, $H$is human capital, and L is labor. Labor is counted by number of people. Physical capital is the set of intermediate goods and is measured in units consumed for a given good in the final goods sector. Human capital refers a given person in particular’s education or training.

In this posture, the different types of capital goods are assumed to be substitutes for the rest, which is to say, there is an expression in which the product is an additive function separable from all of the different types of capital goods, and not as the conventional equation of perfect substitutes for all capital goods suggests.

One fundamental aspect of the position explained here is that knowledge expressed in a new product plays its function in economic output in two ways: *1*) it permits the production of a new intermediate good that can be used to produce output; *2*) it increases the total stock of knowledge and boosts the productivity of human capital in the research sector. In this sense, measuring the total capital as a cumulative sacrificed output evolves with the following function:

$$\dot{K}\left(t\right) = Y\left(t\right) - C\left(t\right) \qquad (2)$$

Because it takes η units of sacrificed consumption (in capital units) to create one unit of some type of durable good, this accounting measure K is related to durable goods that are really used in production under the following rule:

$$K = \eta \sum_{i=1}^{\infty} x_i = \eta \sum_{i=1}^{A} x_i \qquad (3)$$

If the sum in equation (1) is replaced by an integral, because the set of durable goods is treated as a continuous variable, the function is formulated as follows:

$$Y\left(H_Y,\ L,\ x\right) = H_Y^{\alpha} L^{\beta} \int_0^{\infty} x\left(i\right)^{1-\alpha-\beta} di \quad (4)$$

Another important postulate is that there is no rivalry in knowledge as an input. Research has free access to the knowledge stock and researchers can capitalize on its advantages. In this sense, the aggregate stock of the creation of new designs resulting from the efforts of employees working the R+D sector evolves pursuant to the following function:

$$\dot{A} = \delta H_A A \quad (5)$$

Where H_A is the human capital employed in the R+D sector and A is the knowledge stock, considered as a non-rival component of technology. Moreover, one far-reaching assumption inherent to the economic growth model used is that the generation of new products is linear with the human capital employed in the R+D sector and the knowledge stock. In this approach, two assumptions emerge from equation (5): *1)* dedicating more human capital to research leads to a higher production rate for $\dot{A}$; *2)* the higher A is, the higher the productivity will be of a given scientist working in the research sphere.

In addition to that, due to the symmetry of the model, all of the durable goods are available at the same level and are denoted as $\overline{x}$. Because A determines the range of durable goods that can be produced, and η units of capital (product) are required per unit of durable goods, from the equation $K = \eta Ax$, x is isolated and the $x = K / \eta A$ is substituted into equation (4), so the Romer model production function is expressed as:

$$y\left(H_A, L, x\right) = (H_Y A)^{\alpha} (LA)^{\beta} (K)^{1-\alpha-\beta_{\eta}\alpha+\beta-1} \quad (6)$$

In short, the Romer model describes that dedicating more effort to the R+D sector and investment in human capital are central aspects of driving technological progress and attaining higher levels of economic growth. Research about a new design, process, or product takes place inside a company or a set of companies.

If this research results in an invention and it is subject to an evaluation process to see if it is eligible for protection, in the form of intellectual property as a patent, the company owning the patent may concede the exploitation rights or sell the asset in exchange for profit to another company that will use the patent to produce the good.

4. ECONOMETRIC SPECIFICATION

The econometric approach relied on a linear regression model estimated with least ordinary squares (LOS) with a ratio transformation (Gujarati, 2004). This type of transformation is used because the traditional production function generates multi-colinearity, which is a serious problem for a cross-sectional data structure.

The presence of multi-colinearity violates one of the assumptions of the classic linear regression model (CLRM). And, even though the LOS estimators are unbiased, it does not say anything about the properties of the estimators in a given sample. Moreover, even though the LOS estimators are efficient (they have minimum variance), it does not mean that the variance of the estimator will be small with respect to the value of the estimator in any given sample. And, the multi-colinearity is not a phenomenon related to sample regression, meaning that even if the independent variables are not linearly related in the population, but they may be in the sample.

The original model used is a double-log production function:

$$ln\left(Y_i\right) = \beta_1 lnK_i + \beta_2 lnL_i + \beta_3 lnPat_i + u_i$$

Where $ln\left(Y_i\right)$ is the log of GDP and GDP per capita (indicator of economic development) in a given *i*-th state, $ln\left(K_i\right)$ is the log of gross fixed capital formation,[2] $ln\left(L_i\right)$ is the log of the workforce measured by number of occupied persons[3] and wages and salaries,[4] and $ln\left(Pat_i\right)$ is the log of patent applications,[5] the variable used as a proxy for innovation to measure the effect of learning resulting from the accumulation of knowledge in economic growth, and u is the error term.

The way to correct the problem of multi-colinearity was solved by expressing it in a base per capita, dividing the equation by patent applications.

$$ln\left(\frac{Y_i}{Pat_i}\right) = \beta_1 + \beta_2 ln\left(\frac{K_i}{Pat_i}\right) + \beta_3 ln\left(\frac{L_i}{Pat_i}\right) + u_i$$

The other method was to divide the function by wages and salaries to obtain an innovation coefficient.

$$ln\left(\frac{Y_i}{L_i}\right) = \beta_1 + \beta_2 ln\left(\frac{K_i}{L_i}\right) + \beta_3 ln\left(\frac{Pat_i}{L_i}\right) + u_i$$

A patent is that exclusive right granted by the State to protect an innovation, which offers exclusive rights that enable the holder to use and exploit their invention and prevents other institutions, companies, or industries from using it without their consent and without paying the reserved rights. The choice can be made to profit from a patent by implementing it or selling the rights to another company to market it, whether it is a new product or new procedure (IMPI, 2016).

The idea behind patents is to provide an exclusive right to industrial and commercial exploitation. They are very useful instruments to promote corporate growth and can impact a country's economic growth, and, therefore, the company, institution, or country can be highly competitive.

In addition, the variable of human capital was added into the model, measured by the number of members belonging to the National Researchers System (SNI, in Spanish), which is part of the National Science and Technology Council (Conacyt). This variable was added because members in the system comprise a trade association belonging to the R+D sector, and international and national empirical evidence has borne out the idea that there is a positive relationship between this variable and economic growth (Torun and Cicekci, 2007; Bayarcelik and Tasel, 2012; Marroquin and Ríos, 2012; Maradana *et al.,* 2017). Nevertheless, patents were excluded from this model because they are correlated with the SNI, as has been demonstrated by papers in Mexico (Furman *et al.,*2002; Malva and Caree, 2013; Calderón-Martínez, 2014; Cozza and Schettino, 2015; Almendarez-Hernández, 2018). For that reason, the model is expressed as follows:

$$ln\left(\frac{Y_i}{L_i}\right)=\beta_1+\beta_2 ln\left(\frac{K_i}{L_i}\right)+\beta_3 ln\left(\frac{SNI}{L_i}\right)+u_i$$

5. RESULTS

The database contained data from a decade (1998-2008), which was also the study period, containing aggregate data for the entire country. It also happened to be the data that was available from Mexico's different agencies and institutions. To select the variables used in the analysis, we conducted an exhaustive search of all the different sources by state. Information pertaining to gross fixed capital formation, the occupied population, and wages and salaries was obtained from INEGI's economic censuses from the years 1999, 2004, and 2009. The number of patent applications was obtained from the Mexican institute for Industrial Property (IMPI, 2017). To compare the values across the three years, they were deflated using the Implicit Price Index with a base of 1993 for INEGI data.

Table 1 summarizes the central trend measures as the arithmetic mean and the dispersion measures as the standard deviation of the variables used in the estimated models, as well as their minimum and maximum values. Following the order of the square, the mean fixed gross capital formation amounted to 1.152 billion pesos. Occupied persons climbed to 341,125, patents were 5, GDP was 30 billion pesos, and GDP per capita hit 14,222 pesos. Wages and salaries, 2.107 billion pesos.

Table 1. Descriptive Analysis of the Data

Variables	*Mean*	*Standard Deviation*	*Maximum Value*	*Minimum Value*
GFCP	1 152 116	2 948 127	20 476 235	149 328.3
Total occupied persons	341 125	533 286.4	3 131 480	71 375
Patents	5	33.97615	219	0
GDP	3.05E+10	6.145E+10	3.415E+11	7.62E+09
GDP per capita	14 222.64	16 645.58	163 039	6 019.58
Population	2 431 015	2 716 913	14 638 436	409 025
Remuneration	2 621 240	9 495 026	55 861 982	562 764
Wages and salaries	2 107 288	7 215 834	43 050 962	419 521.9
SNI	333	860	6175	2

Source: Created with the constructed database.

The original production function was estimated to check whether there was multi-colinearity. The results show that this problem is indeed present. For the variable of occupation, the sign was opposite to what economic growth theory would hold. As far as the patents coefficient is concerned, the standard errors are too high, meaning that it is not statistically significant at the conventional levels of significance (see Table 2).

Table 2. Estimating the Original LOS Model

Dependent variable of GDP per capita				
Variables	*Coefficient*	*Standard Error*	*t-Statistic*	*Probability*
Constant	7.2159	0.8639	8.35	0.0000
GFCF	0.4086	0.0875	4.67	0.0000
Occupied	-0.2684	0.1058	-2.54	0.0131
Patents	0.0261	0.0439	0.60	0.5529
R^2	0.2787			
F-statistic	10.3048			

Source: Created with the constructed database.

Regressions were run separately. Each variable turned out to be statistically significant with positive signs. The problem of multi-colinearity was corrected using the series of patents, wages, and salaries to normalize the data. In the model with the functional specification of economic development, the null hypothesis that the coefficients of partial slopes were equal to zero was rejected at conventional significance levels (see Table 3).

Table 3. Estimates from the LOS Model to Transform the Ratio with an Economic Development Approach

Dependent variable of GDP per capita				
Variables	*Coefficient*	*Standard Error*	*t-Statistic*	*Probability*
Constant	-2.7944	0.9045	-3.09	0.0027
GFCF/patents	0.4148	0.2385	1.74	0.0858
Occupied people/patents	0.4934	0.2505	1.97	0.0523
R^2	0.6052			
F-statistic	62.0955			

Note: The standard errors are corrected by the White covariance matrix method.

Source: Created with the constructed database.

The F test at the usual significance levels rejected the null hypothesis saying that the real partial slope coefficients were simultaneously equal to zero at 1% significance. Plus, the value of the F test turned out to be higher than in the original model.

One way to measure the goodness of fit of the regression was to use the R^2 determination coefficient, indicating that the proportion or 60% of the total variation in the GDP per capita/patents ratio is explained by the set of independent variables being studied. Estimates were proven using wages and salaries. However, the results were not significant for the wages-patents ratio. The estimated model is expressed in linear terms in the parameters and linear terms in the variable logarithms. The coefficients that result measure elasticities and display the correct (positive) signs pursuant to endogenous growth theory.

The gross fixed capital formation to patents ratio coefficient showed that in response to a 1% increase in this variable, the GDP per capita goes up 0.41%. The ratio of occupied people to patents revealed that for every 1% increase in this regressor variable, the GDP per capita grew by 0.49%. As far as the economic growth model went, the coefficients turned out to be statistically different from zero and the general significance test for the regression was statistically significant at 1%. The gross fixed capital formation to wages and salaries variable was similar to the gross fixed capital formation to patents ratio. The patents, as an indicator of innovation, which is the number one variable of interest in this study, bore out the following: increase it by 1%, and GDP grows approximately 0.05% (see Table 4).

Table 4. Estimates from the Ratio Transformation LOS Model with an Economic Growth Approach

Dependent variable of GDP

Variables	*Coefficient*	*Standard Error*	*t-Statistic*	*Probability*
Constant	10.574	0.2876	36.76	0.0000
GFCF/Wages and salaries	0.416	0.1049	3.97	0.0002
Patents/Wages and salaries	0.0498	0.0241	2.06	0.0426
Year 1998	-0.2618	0.0909	-2.88	0.0051
Year 2003	-0.2404	0.0704	-3.41	0.0010
R^2	0.6052			
F-statistic	62.0955			

Note: The standard errors are corrected by the White covariance matrix method.

Source: Created with the constructed database.

The results here are within the range found in other papers where economic growth and innovation are concerned, and are consistent with international studies by Ulku (2004), Torun and Cicekci (2007), Blind and Jungmittag (2008), Hasan and Tucci (2010), Kim *et al*. (2012), Pece *et al*. (2015), and Guastella and Timpano (2016), as well as national empirical evidence from Marroquín and Ríos (2012), Ríos and Marroquín (2013), Torres-Preciado *et al*. (2014), and Ríos-Flores and Ocegueda (2017). Additionally, to contrast the differences between the GDP years, we used 2009 as a contrast via fictitious variables, showing that the value between 1999 and 2004 was lower than that of 2009 in real terms. The two models used have a good fit. The determination coefficients fluctuated in the range of the cross-sectional studies by Gujarati (2004).

Estimates were tested by divided by occupied people. Even so, the results were not significant for the ratio of patents to occupied. The SNI variable coefficient indicates that there is a positive impact on economic growth. The results are comparable to other national and international research papers that have dealt with the link between people working in science and technology and income (Torun and Cicekci, 2007; Bayarcelik and Tasel, 2012; Marroquín and Ríos, 2012; Maradana *et al.,* 2017) (see Table 5).

Table 5. Estimates from the LOS Model of the Ratio Transformation with the Economic Growth Approach Including the SNI

Dependent variable of GDP

Variables	*Coefficient*	*Standard Error*	*t-Statistic*	*Probability*
Constant	10.5390	0.3812	27.6504	0.0000
GFCF/Wages and salaries	0.4252	0.1197	3.5506	0.0006
SNI/Wages and salaries	0.0889	0.0332	2.6764	0.0090
R^2	0.3337			
F-statistic	20.2837			

Note: The standard errors are corrected by the White covariance matrix method.

Source: Created with the constructed database.

The empirical evidence shown here is indicative that innovation is a major driver of economic growth and economic development. An economic policy that creates enough incentives for economic agents to feel attracted to investing in the R+D sector, in combination with government actions in public spending, can drive greater technological progress, which in turn is the motor for long-term economic growth that an emerging economy like Mexico requires.

To boost the welfare of the people, it is necessary to supply goods that have technology to give them added value and, therefore, trade them at a higher market value.

6. CONCLUSIONS

Considering the roots of the economic base and the factors and sectors derived from it, considering its complexity and diversity, several conclusions emerge. Pursuant to this research, we can assert that there is indeed a close relationship between economic development and innovation through patents; so too is there with economic growth. It is clear that the increase in R+D has positively driven economic growth, and the result of this increase in research is inventions, measured through the indicator of patents.

One of the problems that arises when conducting a regression analysis is multi-colinearity, which is to say, that the explanatory variables in the model are closely related to one another and to try to correct it, the ratio was transformed. That means that each variable was divided among the patents and wages and salaries. A model was expressed in in linear terms in parameters and natural logs in the variables. With this specification, the coefficients obtained were directly interpreted in elasticities, producing positive results pursuant to the theory of endogenous growth.

This theory holds that economic growth is the result of endogenous factors and not external forces, as conventional neoclassical theory proposes. Federal investments in R+D highlight that human capital, innovation, and growth contribute significantly to leveraging economic development and economic growth. The empirical evidence shows that innovations play a key role in economic growth during the time period studied. Good income redistribution and good policy utility could generate the quality intellectual capital needed so that the advantages involved in driving this sector lead to substantial benefits for an economy. Generally speaking, the conclusions is that innovations positively affect economic entities, by generating patents. A clearer way to explain the growth of a given economic entity is to look at the degree of patenting in innovation, but, what is important is to direct that research and innovation toward productive sectors that reflect economic growth, in emerging economies like the Mexican economy.

ACKNOWLDGEMENTS

We would like to thank Mexico's National Science and Technology Council (Conacyt) for the financial support that facilitated this research, the Biological Research Center of the Northeast of Mexico (CIBNOR), and the *Public Intellectual Property Resource* (PIPRA) at the University of California, Davis. Special thanks to Juan Carlos Leyva Poblano and Dr. Gerzaín Avilés Polanco for all of their support in organizing the information for this paper. We also want to thank the anonymous reviewers for their comments to support in improving an earlier version of this manuscript.

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[2] According to INEGI, gross fixed capital formation consists of the total value of acquisitions less fixed asset disposals, plus additions of the value of non-produced assets. Fixed assets, which can be tangible or intangible, are obtained as the result of production processes and are used repeatedly or continuously in other production processes for more than one year.

[3] Occupied people for INEGI include employees and workers, either freelance or staff, which in the reference month worked under the charge or management of the company in the state or out of it (meaning in the state where the company is located or in any other state throughout Mexico) with fixed or set remuneration, covering at least one third of the workday. This figure includes people out on leave for illness, vacation, strike, or temporary leave with or without pay. It excludes people with an unlimited leave, pensioners with fee-based payments, or matching salary or commission earners.

[4] To INEGI, remuneration refers to any payment or contribution in money or in kind before any deduction is made, meant to compensate people working for the enterprise, both in the form of wages and social benefits, or in profits distributed to the personnel, whether calculated on the basis of the workday or the amount of work done (piecework). For this research, only wages and salaries are included.

[5] This variable is composed of the number of patent applications. Information provided by IMPI.

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PROBLEMAS DEL DESARROLLO. REVISTA LATINOAMERICANA DE ECONOMÍA, Volume 49, Number 195 October-December 2018 is a quarterly publication by the Universidad Nacional Autónoma de México, Ciudad Universitaria, Coyoacán, CP 04510, México, D.F. by Instituto de Investigaciones Económicas, Circuito Mario de la Cueva, Ciudad Universitaria, Coyoacán,
CP 04510, México, D.F. Tel (52 55) 56 23 01 05 and (52 55) 56 24 23 39, fax (52 55) 56 23 00 97, www.probdes.iiec.unam.mx, revprode@unam.mx. Journal Editor: Moritz Cruz.
Reservation of rights to exclusive use of the title: 04-2012-070613560300-203, ISSN: pending. Person responsible for the latest update of this issue: Minerva García, Circuito Maestro Mario de la Cueva s/n, Ciudad Universitaria, Coyoacán, CP 04510, México D.F., latest update: January 9th, 2019.

The online journal *Problemas del Desarrollo. Revista Latinoamericana de Economía* corresponds to the printed edition of the same title with ISSN 0301-7036