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Un análisis de la productividad manufacturera de México entre 1988 y 2013

An analysis of Mexico's manufacturing productivity between 1988 and 2013

Uma análise da produtividade industrial do México entre 1988 e 2013

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Resumen

Aunque los sectores de servicios y comercio representan la mayor parte de la economía en muchos países avanzados y en desarrollo, en varios casos el sector manufacturero desempeña un papel fundamental en el desarrollo económico principalmente a través de las exportaciones. Por esa razón, la cuestión de la evolución y las fuentes del crecimiento de la productividad en la actividad manufacturera sigue siendo relevante.

En este trabajo se analiza el cambio de eficiencia técnica y la productividad total de los factores de la manufactura mexicana a nivel de subsector (excluidas las industrias petroleras) en el periodo 1988-2013. Al utilizar el empleo y los activos fijos como insumos y la producción bruta total como producto, se aplica el análisis envolvente de datos (DEA, por sus iniciales en inglés), el índice de Malmquist y su descomposición en dos componentes: cambio técnico y cambio de eficiencia. Los datos provienen de los Censos Económicos —del periodo temporal ya mencionado— realizados por el Instituto Nacional de Estadística, Geografía e Informática (Inegi). Debido a las características productivas de las industrias manufactureras, se espera que cualquier cambio positivo en la productividad en el periodo de estudio se deba al efecto del cambio tecnológico y, en menor medida, al efecto de la eficiencia técnica. La hipótesis es que el cambio en la eficiencia técnica también puede ser negativo, lo que es perjudicial para el crecimiento de la productividad en la manufactura mexicana.

Palabras clave: eficiencia técnica, índice de Malmquist, manufactura, México, productividad.

Abstract

Even though the service and commerce sectors account for the most part of the economy in many advanced and developing countries, in various instances the manufacturing sector plays a fundamental role in economic development mainly via exports. For that reason, the question of the evolution and sources of productivity growth in manufacturing activity keeps relevant.

In this paper, we analyze the technical efficiency change and total factor productivity in the Mexican manufacturing at the subsector level (excluding oil industries) in the period 1988-2013. By using employment and fixed assets as inputs and total gross production as output, we apply Data Envelopment Analysis, the Malmquist index and their decomposition into its two components "technical change" and "efficiency change". The data come from the 1988 to 2013´s economic censuses carried out by the national Institute of Statistics, Geography and Informatics. Due to the productive characteristics in manufacturing industries we expect that any positive changes in productivity in the study period were driven by the "frontier shift" (technological change) effect and, to a lesser extent, by the "catching up" effect (technical efficiency change). We hypothesize that technical efficiency change can also be negative, which is detrimental to productivity growth in Mexican manufacturing.

Keywords: technical efficiency, Malmquist index, manufacturing, Mexico, productivity.

Resumo

Embora os setores de serviços e comércio representem a maior parte da economia em muitos países desenvolvidos e em desenvolvimento, em vários casos o setor manufatureiro desempenha um papel fundamental no desenvolvimento econômico, principalmente por meio das exportações. Por essa razão, a questão da evolução e as fontes de crescimento da produtividade na atividade manufatureira continuam sendo relevantes.

Este artigo analisa a mudança na eficiência técnica e a produtividade total dos fatores de fabricação mexicanos no nível dos subsetores (excluindo as indústrias de petróleo) no período 1988-2013. mudança técnica e mudança: Usando o emprego e imobilizado como entradas e produção do produto bruto total, análise envoltória de dados (DEA inicial Inglês), o índice de Malmquist e a sua decomposição em dois componentes aplicados de eficiência. Os dados são provenientes do Censo Econômico - do referido período - realizado pelo Instituto Nacional de Estatística, Geografia e Tecnologia da Informação (Inegi). Devido às características de produção de fabricação, espera-se que qualquer mudança positiva no período de estudo de produtividade devido ao efeito da evolução tecnológica e, em menor medida, o efeito da eficiência técnica. A hipótese é que a mudança na eficiência técnica também pode ser negativa, o que é prejudicial ao crescimento da produtividade na manufatura mexicana.

Palavras-chave: eficiência técnica, índice de Malmquist, manufatura, México, produtividade.

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Introduction

In the last three decades, the manufacturing industry in Mexico has gone through both conjunctural and structural changes brought about by various events, from national and international recessions, the completion of the import substitution model, the implementation of the neoliberal model, the new economic geography global, among others, which have been studied under different perspectives: sectoral, regional, temporal, comparative, national and international, as well as with different methodologies. Several authors agree that this industry has been the fundamental basis of economic development and axis of world trade, despite the relative decline in their participation in the commerce and services sector (Mendoza, 2010, Sobrino, 2016, Trejo, 2017).

During this period, Mexican manufacturing has gone through two stages: the first from 1989 to 2000, where there was a recovery and opening to register a growth of 4.5% and in the second, from 2001 to 2013, where a stagnation was observed, falling at 1.1% in terms of the gross value of production (VBP). In the analysis period, the highest productivity was reached in 1980 (380,000 pesos per person) measured in terms of labor productivity, while in the nineties it was reduced, and in the most recent decades it has remained unchanged. This industry showed a structural change given the difference in the percentages of what was produced in 1980, 96% was sold to domestic consumption and 4% was exported, while in 2008 66% was destined to domestic consumption and 34% to export (Sobrino, 2016).

In the first phase, the manufacturing activity went through the completion of the import substitution model and the implementation of the neoliberal model. According to Sobrino (2016), this activity was strongly associated with international markets, as a result of the implementation of the North American Free Trade Agreement (NAFTA) in 1994. A large part of the dynamism of the manufacturing sector was determined by the flows of foreign direct investment (FDI) channeled to that sector (Mendoza, 2010). Manufacturing growth in the 1996-2005 period was closely linked to exports of intermediate and final goods from the manufacturing sector (and maquila).

In the second stage, the growth of manufacturing activity was reduced: since 2000, FDI flows began to decline, a situation that worsened further as a result of the international recession (2001 and 2002). For the year 2004, however, a rebound was observed, although in 2007 and 2008 total FDI in Mexico fell again (Mendoza, 2010). The impact of the international recession, especially in the United States of America (USA), has highlighted the limitations of Mexico's economic model, particularly in relation to the high dependence of the external and manufacturing sectors on the growth dynamics of Mexico. the American economy.

Mendoza (2010) affirms that the Mexican manufacturing sector was one of the most affected by the recession of the US economy, since having a high degree of synchronization of the economic cycle of these sectors generates a dependence on the behavior of manufacturing in Mexico with regarding the evolution of manufacturing production in the US. The transportation equipment sub-sector was the most adversely affected by the international recession and to a lesser extent the subsector of the manufacture of computers, communication and electronic equipment and production of furniture, textiles and clothing; despite this, they managed to generate more than 60% of manufacturing exports in 2012 (Chávez and García, 2015).

In the regional context, Rendón, Mejía and Salgado (2013) point out that there are several factors that explain the differences in economic growth, be it investment in human and physical capital, research and development, education, political stability, specialization productive, among others. In this regard, the work of Becerril, Díaz, and Del Moral (2013, p.18) is pointed out, who calculate productivity using the Malmquist index for the socioeconomic regions of Mexico from 1970 to 2008, finding an improvement due to the increases in the technical change, originated by the development of technological incorporation processes; except in region two (Campeche, Hidalgo, Puebla, Veracruz, San Luis Potosí, Tabasco y Veracruz).

The cities and regions of the northern states, centronorte (Mexico City, State of Mexico, Puebla, Querétaro) and El Bajío (Jalisco, Guanajuato) are the most benefited by the economic dynamics (Trejo, 2017), and in relation to The branches, due to their productive, technological and commercial peculiarities, experience the effects of opening and liberalization in an asymmetric manner, with export industries being more favored.

In terms of productivity at the national level, in average terms in the last three decades no significant changes have been observed in the best use of productive factors, according to Martínez, Brambila and García (2013). Padilla and Guzmán (2010), on the other hand, observe that in this period the total factor productivity in the national manufacturing registered a growth of only 0.5% annual average; In addition, the behavior of this sector is highly polarized, as well as economic growth.

The differences between regions, as well as between sub-sectors, in terms of value added per worker, can be attributed to differences in physical capital, in the labor factor and in productivity (Hall and Jones, 1999). An important source of productivity is technical efficiency, which refers to the capacity of an economic unit to avoid wasting resources in the production process through producing the amount that technology and the use of inputs allow (Fried, Lovell and Schmidt, 2008). Therefore, technical efficiency indicates the potential for economic growth, keeping inputs and technology constant (Chávez y Fonseca, 2012).

To measure technical efficiency, it is necessary to compare current performance with optimal performance, represented by a production frontier integrated by efficient points. The methodologies commonly used to obtain estimates of technical efficiency are two: the first involves a parametric production function, estimated through regressions; and the second is done through the nonparametric method represented by the data envelopment analysis (DEA). Among the advantages offered by this last technique, is the emphasis on flexibility, since it allows modeling the underlying technology. Unlike the parametric technique that must assume a specific functional form for the production function, the DEA, on the other hand, allows us to ignore this assumption, in such a way that it is only necessary to assume a series of properties for the set of production possibilities.

In this study, the DEA has been chosen as the basic methodology to analyze the productive efficiency and the change of the total factor productivity of 20 subsectors of Mexican manufacturing, in the years of 1988, 1993, 1998, 2003, 2008 and 2013. However, the manufacturing industry, due to its own dynamism, carries with it the importance of studying its behavior in terms of efficiency over time, so we are faced with the situation of how to capture the time factor in the DEA. Given this, because the conventional DEA model for now only allows to calculate the efficiency index for different units in a single moment of time, it has been decided to resort to the Malmquist index (non-parametric approach) as a main methodology, since it allows to approximate the change in the total factor productivity of a given unit in a period of time. In addition, this index is broken down into two components: first, to analyze the change in technical efficiency, and second, to approximate the technical change or the effect of technological innovation materialized in the displacement of the production frontier.

The present investigation is related to other studies that have measured the technical efficiency for manufacturing production in Mexico in different areas. Bannister and Stolp (1995) analyzed the technical efficiency in a set of manufacturing industries for a cross section of the Mexican states in 1985. Braun and Cullmann (2011) estimated the technical efficiency in the Mexican manufacturing sector by applying the random effects model for a data panel at the municipal level for the years 1989, 1999 and 2004. Chávez and Fonseca (2012) applied a translogarithmic stochastic frontier function to analyze the evolution of technical efficiency in the manufacturing industry as a source of regional economic growth for the period 1988-2008. Becerril et al. (2013) analyze the technological frontier and the total factor productivity (PFT) of the regions of Mexico. None of these studies addresses technical efficiency at the sub-sector level and its evolution over time through a non-parametric technique; all tend to use the parametric methodology, except Brown and Dominguez (2004 and 2013), who analyze the PFT of the manufacturing industry and its components in two periods: from 1984 to 1993 and from 1994 to 2000; and then the periods 1994-2001 and 2001-2009, at the level of establishments, through the

Malmquist index. However, they also did not explicitly estimate differences in the level of technological development at the sub-sector level. Therefore, the present study seeks to know the internal dynamics of Mexican manufacturing in order to analyze the evolution of technical efficiency and its differences among subsectors, as well as to study the behavior of the total productivity of its factors and its components. For which, as already mentioned, the DEA and the Malmquist index are used with a data panel for the period 1988-2014, where the units of analysis are the manufacturing sub-sectors.

Method

The enveloping data analysis (DEA)

The DEA is a nonparametric and deterministic procedure that uses linear programming techniques to evaluate the relative efficiency of a set of homogeneous units. The mathematical formulation of the enveloping version reflects a good adaptation to the notion of Farrell's technical efficiency in terms of output, by virtue of which a unit is considered efficient when no other is able to produce more using less inputs.

Malmquist Index

The Malmquist index allows to approximate the changes that occur in the TFP of a given productive unit between two periods, t and t + 1, calculating the ratio of the distances of each period relative to a common technology (Coelli, Prasada and Battese 1998) . The calculation of the index allows to decompose the TFP of a productive unit in the change due to the improvement of technical efficiency (and this in turn in pure efficiency and scale efficiency) and that due to technical change or technological progress.

This methodology is based on the calculation of the distance that separates each decision making unit (DMU) or productive unit from the reference technology in each period using the distance function. These distance functions allow to describe the multi-input and multi-output production technology without the need to specify a behavioral objective (as well as cost minimization or profit maximization) and to define distance input functions and distance output functions. A distance-output function characterizes production technology by observing a proportional maximum expansion of the output vector, given an input vector (Coelli et al., 1998).

In the present work, the distance functions oriented to the output are considered, orientation that is more appropriate, since the objectives of the productive units are translated in reaching the highest possible levels of product, given the existent resources, and not in achieving an determined product with a minimum level of inputs. Because it is a matter of comparing the evolution of productivity, the Malmquist index requires distance functions with respect to different periods of time. Therefore, in a subsequent period t + 1, the distance function is defined as:

$$D^t(x^{t+1}, y^{t+1}) = \min\{\emptyset : (y^{t+1} /\emptyset) \in P^t (x)\} \tag{1}$$

This function measures the maximum proportional change in the outputs necessary for (x^{t+1}, y^{t+1}) is feasible with the technology of period t. In this case, the value of the distance function can exceed the unit, because the evaluated entity is not possible with the technology of another period.

From these distance functions, Malmquist productivity index oriented to output and referred to the technology of period t is defined as:

$$M_o^t(x, y) = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \tag{2}$$

Analogously, the Malmquist index oriented to the output and referring to the technology of period t + 1 is defined, for which the corresponding distance functions must be used, so that:

$$M_o^{t+1}(x, y) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \tag{3}$$

Expressing the index oriented to output and referring to production technology in the period *t* (S^t), in geometric terms it is observed that it coincides with the change in Malmquist's productivity index in terms of vertical distances over the technology of the period *t*:

$$M_o^t\,(x, y) = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} = \frac{\frac{0d}{0c}}{\frac{0a}{0b}} = \frac{\frac{0d}{0a}}{\frac{0c}{0b}} \tag{4}$$

And similarly, the index oriented to output and referred to technology S^{t+1} is defined in geometric terms as:

$$M_o^{t+1}(x,y) = \frac{D_o^{t+1}(x^{t+1},y^{t+1})}{D_o^{t+1}(x^t,y^t)} = \frac{\frac{0d}{0f}}{\frac{0a}{0g}} = \frac{\frac{0d}{0a}}{\frac{0f}{0g}} \quad (5)$$

Where the value allows to approximate the change of the total factor productivity in the period t + 1, measured this in terms of vertical distances on the technology S^{t+1}.

The measure provided by both indexes does not have to coincide because it is conditioned by the technology used as a reference. To solve this problem, Färe, Grosskopf, Norris and Zhang (1994) propose to approximate the change in productivity from the geometric mean of both previous Malmquist indices. Therefore, the index is definitively calculated as:

$$M_o(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\left(\frac{D_o^t(x^{t+1},y^{t+1})}{D_o^t(x^t,y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1},y^{t+1})}{D_o^{t+1}(x^t,y^t)}\right)\right]^{1/2} \quad (6)$$

A value of this index higher than unity is indicative of productivity growth between the two periods (improvements in productivity), while if it takes values lower than unity implies a decrease in productivity between the two periods (losses).

This index can be disaggregated into two components that approximate the change in technical efficiency and technical change. Färe et al. (1994) demonstrated this decomposition through simple mathematical operations, allowing an equivalent way of expressing this index as:

$$M_o(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_o^{t+1}(x^{t+1},y^{t+1})}{D_o^t(x^t,y^t)} * \left[\left(\frac{D_o^t(x^{t+1},y^{t+1})}{D_o^{t+1}(x^{t+1},y^{t+1})}\right)\left(\frac{D_o^t(x^t,y^t)}{D_o^{t+1}(x^t,y^t)}\right)\right]^{\frac{1}{2}} = CET * CT \quad (7)$$

From the above expression it is deduced that the total change of the Malmquist index can be decomposed into two terms. The first term (CET) measures the change in technical efficiency [1] or the effect (catching up), that is, the degree of convergence to the frontier of production possibilities experienced by the subsector analyzed in the study period. If the value of this component is greater than one, said subsector tends to approximate the production boundary. If it is equal to one, the distance with respect to the border is the same. If it is less than one, it corresponds to efficiency losses.

The second term (TC, the geometric mean of the two ratios included in the brackets) approximates the technical change or the technological innovation effect materialized in the displacement of the production frontier (shift frontier). This change quantifies the average distance between the production functions of the two periods in the levels of use of inputs in xt and xt + 1. If there have been technological improvements, this component registers values higher than unity, which indicates the existence of technical progress.

Furthermore, it should be borne in mind that, although the product of the change in technical efficiency and technical change must, by definition, be equal to the Malmquist index, these two components may have behaviors in opposite directions.

Coelli et al. (1998) emphasize that the properties of technology-scale performance are very important in the measurement of TFP. Grifell-Tatjé and Lovell (1995) use a simple example with an input and a single output to illustrate that a Malmquist PTF index may not correctly measure changes in TFP when variable returns to scale (VRS) are assumed for the technology. Therefore, it is important that constant returns to scale (CRS) are imposed on any technology that is used to estimate distance functions for the calculation of a Malmquist PTF index. Otherwise, the resulting measures may not properly reflect the TFP gains or losses resulting from scale effects. Therefore, this paper assumes constant returns to scale to measure the change in total factor productivity through the Malmquist index under an output orientation.

[1] Färe, Grosskopf y Lovell (1994) propusieron una ampliación de esta aproximación de forma que se puede desagregar el cambio en la eficiencia técnica en dos componentes: cambio en la eficiencia técnica pura y cambio en la eficiencia de escala (bajo el supuesto de rendimientos variables a escala).

Results

The information used in the calculation of the index comes from the Economic Censuses (1988, 1993, 1998, 2003, 2008, 2013), grouping the data in 20 manufacturing sub-sectors (excluding the oil industry), in accordance with the Industrial Classification System of North America [SCIAN] (2007). The gross value added manufacturing represents 16.54% of the gross domestic product (GDP) at constant prices (base 2008) of the National Accounts of 2008, while for 2003 this value was 17.56%, noticing a decrease of one percentage point. In terms of the employed population, manufacturing activity observed shares of 15.89% and 16.74% for 2008 and 2005, respectively, with data from the National Occupation and Employment Survey (ENOE). The interest of this research has been to carry out a long-term analysis to observe trends between the different years and to systematically appreciate patterns of behavior in terms of technical efficiency and technological change.

The empirical model is estimated for the manufacturing sector, excluding the oil industry, as already noted, using a balanced panel for 20 manufacturing sub-sectors, for the years 1988, 1993, 1998, 2003, 2008, 2013. It was used as a measure of the product the total gross production of each industrial subsector, the personnel employed as a measure of the labor factor, while the capital factor approximates fixed assets (both the product and the capital are measured in constant base 2003 pesos). These variables were obtained from the different Economic Censuses of the National Institute of Statistics, Geography and Informatics (Inegi).

The subsectors that register the greatest participation in all the variables in the different years of study are the food industry, the chemical industry and the manufacture of transport equipment. They also highlight the manufacture of clothing, the manufacture of machinery and equipment, although with lower percentages.

During the period of study (1988-2013), in the Mexican manufacturing sector at subsector level, a heterogeneous behavior has been observed given the scarce technological change and the almost zero technical efficiency. The Malmquist index showed that most of the manufacturing sub-sectors have registered a change due mainly to technological change and to a lesser extent to technical efficiency.

Technical efficiency

The results show that the technical efficiency in the 20 manufacturing subsectors of Mexico increased by 3.07% in average terms from 1988 to 1998, while it decreased in 4.67% from 1998 to 2008, where only the chemical industry sub-sector remains efficient in the study period. Subsectors such as the transport industry and the food industry reflect an increase in the efficiency index that places them at the efficient frontier in only three years of study. The wood industry is striking, that of being inefficient in the years 1988 and 1993 becomes efficient in the last three years of study. The basic metal industries and the computer equipment, communication, measurement and other equipment, electronics components and accessories subsector registered inefficiency only in 1988 and in the rest of the period they managed to reach the optimum production frontier.

The subsectors of the paper industry and other manufacturing industries decreased their performance achieved in 1988 by being inefficient in other years. And the ones farthest from the efficiency frontier are the subsectors of manufacturing products based on non-metallic minerals, manufacturing textile inputs and printing and related industries throughout the study period.

By disaggregating the results on an annual basis, it is observed that in all the years of study, one third of Mexican manufacturing is efficient, while the rest shows a certain degree of technical inefficiency. This is an indication of the removal of most of the subsectors of the optimal production frontier. The behavior of each subsector can be seen in table 3, which is part of the Annex. In Table 1, on the other hand, the efficient sub-sectors are broken down in the study period and the average of the efficiency of the total.

Tabla 1. Subsectores manufactureros eficientes y eficiencia promedio 1988-2008

1988	1993	1998	2003	2008
Confección de productos textiles, excepto prendas de vestir	Otras industrias manufactureras	Industria de la madera	Industria de la madera	Industria de la madera
Fabricación de productos de cuero, piel y materiales sucedáneos, excepto prendas de vestir	Fabricación de equipo de computación, comunicación, medición y de otros equipos, componentes y accesorios electrónicos	Confección de productos textiles, excepto prendas de vestir	Confección de productos textiles, excepto prendas de vestir	Fabricación de productos de cuero, piel y materiales sucedáneos, excepto prendas de vestir
Fabricación de prendas de vestir	Fabricación de prendas de vestir	Fabricación de productos de cuero, piel y materiales sucedáneos, excepto prendas de vestir	Fabricación de productos de cuero, piel y materiales sucedáneos, excepto prendas de vestir	Fabricación de prendas de vestir
Industria del papel	Industrias metálicas básicas	Industrias metálicas básicas	Industrias metálicas básicas	Industrias metálicas básicas
Industria alimentaria	Industria alimentaria	Fabricación de maquinaria y equipo	Fabricación de equipo de computación, comunicación, medición y de otros equipos, componentes y accesorios electrónicos	Fabricación de equipo de computación, comunicación, medición y de otros equipos, componentes y accesorios electrónicos
Fabricación de equipo de transporte	Industria química	Fabricación de equipo de computación, comunicación, medición y de otros equipos, componentes y	Fabricación de equipo de transporte	Industria química

		accesorios electrónicos		
Industria química	Fabricación de equipo de transporte	Industria química	Industria alimentaria	
		Fabricación de equipo de transporte	Industria química	
79.18	**78.62**	**82.25**	**82.32**	**77.58**

Fuente: Elaboración propia

Malmquist Index

Changes in productivity in the study period are summarized in Table 2. The change in total factor productivity experienced by the manufacturing sub-sectors (excluding the oil subsector) as a whole registers an average of 9.0% per five-year period, observing that in the periods of 1993-1998 and 2003-2008 the averages are lower, 2.2% and 0.3%, respectively. From an examination of the components of the Malmquist productivity index, this result is explained by a technological change in average terms of 13 percentage points, and by a change in technical efficiency of -3.8 on average per five-year period. Thus, the increases in productivity of the manufacturing sub-sectors in Mexico are a consequence of a technological change rather than a change in technical efficiency.

Tabla 2. *Malmquist index summary of annual means*

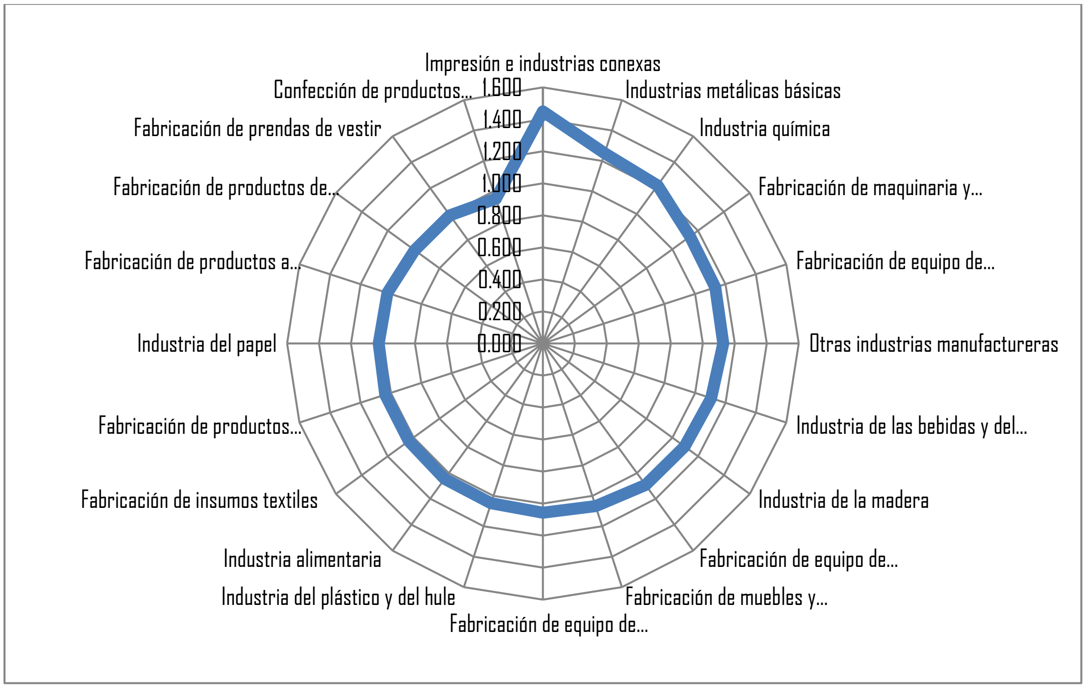
All manufacturing subsectors	*Technical efficiency change index*	*Technology change index*	*Malmquist productivity change index*
1988/1993	1.005	1.185	1.192
1993/1998	0.958	1.067	1.022
1998/2003	0.937	1.071	1.003
2003/2008	0.950	1.214	1.153
2008/2013	1.041	0.920	0.957
All years mean	0.977	1.086	1.062

Fuente: Elaboración propia

An individualized analysis of the results allows observing very differentiated behaviors among the manufacturing subsectors. Of the 20 subsectors under study, 17 reflect positive changes in total factor productivity, including both capital-intensive and labor-intensive ones. It should be noted that these increases in the index are the result of a strong positive technological change combined with a change in positive technical efficiency in 44% of the subsectors and negative in the remaining 56% of the industry (see tables 4 and 5, which are part of the Annex).

If we look at the evolution of total factor productivity (see figure 1), the subsector that has grown the most in average terms is that of printing and related industries, with a Malmquist index of 1.45, while the manufacturing subsector of Non-metallic mineral products recorded the lowest positive change with an index of 1,023, which means that, in the period analyzed, these industries have been placed on the efficiency frontier due to the adoption of technological improvements in the process of the transformation of its inputs into outputs and the efficient use of its technical resources.

Figura 1. *Malmquist productivity*



Fuente: Elaboración propia

Discussion

The estimations that this research throws are consistent with those of other authors, in the sense that the importance of the manufacturing industries in the Mexican economy and its behavior are analyzed, with a distinction in productivity and technical efficiency.

In this regard, Pérez (2008) performs a factorial analysis (analysis of multiple correspondences) of the National Innovation Survey (ENI) of 2001 for the Mexican manufacturing sector, with the objective of finding the innovation patterns of the companies. It examines the innovative activity and economic performance of 531 manufacturing companies that spend on innovation with a base of 77 variables, finding seven conglomerates or patterns of innovation (leading companies, potential leaders, close followers, followers, opportunists, imitators and traditional). In the first conglomerate, leading companies, we have the companies with the highest levels of innovation spending, as well as human capital and formality of innovation activities; Here the secondary chemicals, pharmaceuticals and medicines industry predominate, other manufacturing branches (textile, metallic, non-metallic) and the production of furniture and the like; its propensity to export is high. In general terms, these are companies in the high and medium technology branches. Cluster two has companies that have an average level of expenditure, both in human capital and with regard to the formality of innovation activities, such as those of the automotive industry, production of equipment, electrical and glass appliances and accessories and their products, and have a medium-high export orientation.

Conglomerate three includes companies with average expenditure levels, as well as human capital and formality of innovation activities, although they have the highest investment in training. These are from the pharmaceutical and medicinal industry, secondary chemicals and automotive, with a propensity to export high. Group four is composed of companies with average expenditure levels, as well as human capital and formality of innovation activities, and low level of investment in research and development (R & D); belong to this industry dedicated to the production of bread, cookies and the like, machinery not assignable to a specific activity, automotive industry and production of beverages, with an orientation to exports of low average.

Cluster five includes the industry dedicated to the production of beverages and paper, cardboard and its products, with a low orientation towards exports. They are companies with levels of expenditure on average innovation, and register a low level of investment in training. Cluster six is an aggregate of companies with low levels of innovation spending, as well as human capital and formality of innovation activities; it is integrated by small companies dedicated to the production of furniture and similar, footwear, coke, asphalt and lubricants and other goods based on non-metallic minerals. Finally, cluster seven is integrated by companies with low levels of innovation spending, as well as human capital and formality of innovation activities, dedicated to the automotive industry and basic chemicals.

Said author found that in Mexican manufacturing companies there is a high participation of imitation processes in the innovation patterns of manufacturing companies (41.3%). Likewise, the groups of companies (close followers) that are close to the technological leaders represent a majority proportion (42.2%) of the innovative companies and the conglomerate of companies that base their competitiveness on their innovative activity and therefore promote the systemic competitiveness of the entire industry only represents 16.4%, the latter being those that must be encouraged so that their effect can be replicated to the totality of industrial activity.

In relation to the different types of companies, it is worth mentioning the classification of Pavitt (1984), who identifies the characteristics of the manufacturing sectors based on their technological attributes, namely: 1) companies dominated by the supplier (textiles, wood, paper, products based on non-metallic minerals, among others); 2) production-intensive companies (automotive industry, household appliances, steel, organic and inorganic chemistry, non-ferrous metals, cement and glass), and 3) science-based companies (chemical, pharmaceutical, telecommunications and information technology).

Quiroga y Torrent (2015) They show that new sources of productivity, such as information and communication technologies (ICT), human capital and organizational practices, have as much relevance in the production process as physical capital itself, as long as they are combined in appropriate form within the production function. It should be pointed out that in Latin American countries, co-innovation processes are weak, have low ITC indices and carry out inappropriate institutional practices; In contrast, the case presented in member countries of the Organization for Economic Co-operation and Development (OECD), since they have strengths in productivity and innovation.

In the work of Cubel, Esteve, Sanchis and Sanchis (2011) it is affirmed that the investment in human capital is a determinant of the evolution of the total productivity of the factors. Distinguish between stock of domestic and foreign innovation, indicating a greater weight of foreign innovation in the PFT the greater the degree of commercial openness in the country, this is generated when imports come from the most innovative countries, which are those that incorporate greater knowledge in the goods generated in the exporting countries.

Finally, Rendón, Mejía and Salgado (2013) confirm that the most dynamic economic sectors with the highest level of technology are those that register the highest growth; Therefore, if these sectors are located in the same region, there will be differences in regional growth. Likewise, they point out that manufactures with high technological content constitute the industry where the greatest learning processes are generated, thereby developing increases in productivity and, therefore, in production.

Conclusions

The empirical results of the Malmquist index confirm that the positive changes in manufacturing productivity in Mexico from 1988 to 2013 are the result of a change in the efficient frontier and in a smaller proportion of the approach to the border. Likewise, negative values are reflected in the change in technical efficiency, causing a decrease in the growth of Mexican manufacturing productivity.

The results of the present study are closely linked to the classification elaborated by Pavitt (1984), as well as to the evidence found by Pérez (2008), in the sense that the subsectors with the highest productivity are in the category of companies based on science and in the cluster of leaders in innovation patterns, who drive the systemic competitiveness of the industry.

Technical efficiency, when calculated as a single component, allows us to corroborate that those subsectors with negative changes in this area are the ones that base their productivity growth on technological change, according to the Malmquist index; Therefore, if this inefficiency is transformed into technical efficiency, around 50% of manufacturing would achieve positive rates in terms of total factor productivity.

Part of the research agenda is to generate an econometric model with panel data that allows analyzing the productivity indicator by regions obtained in this study through other economic variables.

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Anexo

Tabla 3. Resultados de eficiencia técnica por Subsector manufacturero en 1988-2008

1988		1993		1998		2003		2008	
Unit	Score	Unit	Score	Unit	Score	Unit	Score	Unit	Score
Sub4	100	Sub21	100	Sub7	100	Sub7	100	Sub7	100
Sub6	100	Sub17	100	Sub4	100	Sub4	100	Sub6	100
Sub5	100	Sub5	100	Sub6	100	Sub6	100	Sub5	100
Sub8	100	Sub14	100	Sub14	100	Sub14	100	Sub14	100
Sub1	100	Sub1	100	Sub16	100	Sub17	100	Sub17	100
Sub19	100	Sub11	100	Sub17	100	Sub19	100	Sub11	100
Sub11	100	Sub19	100	Sub11	100	Sub1	100	Sub20	97.81
Sub14	95.03	Sub2	88.07	Sub19	100	Sub11	100	Sub19	96.29
Sub17	89.31	Sub4	84.71	Sub1	94.83	Sub18	99.44	Sub4	90.79
Sub12	80.03	Sub6	83.61	Sub2	91.16	Sub16	94.06	Sub1	88.44
Sub16	79.92	Sub20	83.55	Sub18	81.07	Sub20	89.56	Sub16	84.7
Sub20	78.66	Sub16	81.61	Sub5	80.03	Sub5	84.42	Sub21	79.72
Sub15	75.81	Sub18	72.73	Sub12	74.24	Sub2	83.58	Sub18	69.9
Sub2	72.88	Sub8	65.7	Sub21	74.06	Sub8	78.32	Sub8	63.08
Sub21	72.86	Sub9	63.47	Sub8	71.4	Sub12	66.46	Sub15	57.79
Sub18	66.92	Sub12	57.43	Sub20	68.88	Sub9	59.78	Sub2	53.38
Sub3	58.5	Sub15	55.37	Sub15	63.39	Sub21	58.36	Sub12	51.96
Sub7	53.59	Sub7	55.21	Sub9	52.87	Sub15	56.67	Sub3	51.79
Sub13	47.18	Sub3	43.08	Sub3	50.54	Sub13	41.68	Sub9	42.99
Sub9	12.88	Sub13	37.86	Sub13	42.54	Sub3	34.02	Sub13	22.97
Average	79.18		78.62		82.25		82.32		77.58

Sub1	Industria alimentaria
Sub2	Industria de las bebidas y del tabaco
Sub3	Fabricación de insumos textiles
Sub4	Confección de productos textiles, excepto prendas de vestir
Sub5	Fabricación de prendas de vestir

Sub6	Fabricación de productos de cuero, piel y materiales sucedáneos, excepto prendas de vestir
Sub7	Industria de la madera
Sub8	Industria del papel
Sub9	Impresión e industrias conexas
Sub11	Industria química
Sub12	Industria del plástico y del hule
Sub13	Fabricación de productos a base de minerales no metálicos
Sub14	Industrias metálicas básicas
Sub15	Fabricación de productos metálicos
Sub16	Fabricación de maquinaria y equipo
Sub17	Fabricación de equipo de computación, comunicación, medición y de otros equipos, componentes y accesorios electrónicos
Sub18	Fabricación de equipo de generación eléctrica y aparatos y accesorios eléctricos
Sub19	Fabricación de equipo de transporte
Sub20	Fabricación de muebles y productos relacionados
Sub21	Otras industrias manufactureras

Fuente: Elaboración propia

Tabla 4. *Geometric mean changes in technical efficiency, technology and Malmquist productivity by Manufacturing Subsector 1988-2008*

No.	***Manufacturing Subsector***	***Technical efficiency change index***	***Technology change index***	***Malmquist productivity change index***
9	Impresión e industrias conexas	1.322	1.097	1.450
14	Industrias metálicas básicas	1.038	1.204	1.249
11	Industria química	1.000	1.220	1.220
16	Fabricación de maquinaria y equipo	0.993	1.147	1.138
18	Fabricación de equipo de generación eléctrica y aparatos y accesorios eléctricos	1.092	1.130	1.134
21	Otras industrias manufactureras	1.034	1.091	1.128
2	Industria de las bebidas y del tabaco	0.913	1.211	1.106
7	Industria de la madera	1.003	1.093	1.096
17	Fabricación de equipo de computación, comunicación, medición y de otros equipos, componentes y accesorios electrónicos	1.025	1.066	1.092
20	Fabricación de muebles y productos relacionados	1.010	1.059	1.069

19	Fabricación de equipo de transporte	0.904	1.169	1.057
12	Industria del plástico y del hule	0.902	1.164	1.049
1	Industria alimentaria	0.924	1.131	1.045
3	Fabricación de insumos textiles	0.864	1.200	1.037
15	Fabricación de productos metálicos	0.934	1.111	1.037
8	Industria del papel	0.837	1.227	1.027
13	Fabricación de productos a base de minerales no metálicos	0.833	1.228	1.023
6	Fabricación de productos de cuero, piel y materiales sucedáneos, excepto prendas de vestir	0.937	1.058	0.991
5	Fabricación de prendas de vestir	0.983	1.007	0.990
4	Confección de productos textiles, excepto prendas de vestir	0.886	1.074	0.952
	Mean	0.962	1.132	1.090

Fuente: Elaboración propia

Tabla 5. *Geometric mean changes in technical efficiency, technology and Malmquist productivity by Manufacturing Subsector 1988-2013*

	Manufacturing Subsector	Technical efficiency change index	Technology change index	Malmquist productivity change index
9	Impresión e industrias conexas	1.294	1.070	1.385
18	Fabricación de equipo de generación eléctrica y aparatos y accesorios eléctricos	1.060	1.095	1.161
14	Industrias metálicas básicas	1.030	1.115	1.148
11	Industria química	1.000	1.115	1.115
16	Fabricación de maquinaria y equipo	1.006	1.108	1.115
19	Fabricación de equipo de transporte	1.000	1.115	1.115
2	Industria de las bebidas y del tabaco	0.951	1.113	1.058
3	Fabricación de insumos textiles	0.917	1.149	1.054
1	Industria alimentaria	0.955	1.096	1.047
7	Industria de la madera	0.979	1.067	1.044
13	Fabricación de productos a base de minerales no metálicos	0.925	1.127	1.043
6	Fabricación de productos de cuero, piel y materiales sucedáneos, excepto prendas de vestir	1.002	1.039	1.041
21	Otras industrias manufactureras	0.978	1.065	1.041

20	Fabricación de muebles y productos relacionados	0.993	1.040	1.033
12	Industria del plástico y del hule	0.911	1.122	1.021
15	Fabricación de productos metálicos	0.940	1.081	1.016
8	Industria del papel	0.894	1.123	1.004
17	Fabricación de equipo de computación, comunicación, medición y de otros equipos, componentes y accesorios electrónicos	0.953	1.046	0.997
5	Fabricación de prendas de vestir	0.980	0.999	0.980
4	Confección de productos textiles, excepto prendas de vestir	0.850	1.052	0.894
	Mean	0.977	1.086	1.062

Fuente: Elaboración propia

Rol de Contribución	Autor (es)
Conceptualización	Angélica María Vázquez Rojas
Metodología	Angélica María Vázquez Rojas
Software	No aplica
Validación	Angélica María Vázquez Rojas
Análisis Formal	Angélica María Vázquez Rojas
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