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Dynamics of Manufacturing Productivity in the Northern Mexican Border, Regional, and by States: 1993-2018

Dinámica de la productividad manufacturera en la frontera norte mexicana, regional y por estados: 1993-2018

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ABSTRACT

The objective of this article is to describe the performance of the total productivity of the manufacturing factors in the Northern border region of Mexico during the period 1993-2018. The methodological approach is focused on Solow's Residual and Harberger's Sunrise/Sunset diagrams to identify the contributions of each of the states. The main findings of the research indicate significant increases in the sources of growth for the region. In addition, the region's progress is diversified among the entities, with Nuevo León being the most prominent. It is concluded that the northern border region has become the largest pole of job creation in the country's manufacturing sector, although it has been limited in terms of total factor productivity. This makes it necessary to develop intraregional policies with specific measures that improve aggregate productivity in each state.

Keywords: 1. manufacturing, 2. total factor productivity, 3. regional economic growth, 4. Northern border, 5. Mexico.

RESUMEN

El objetivo del artículo es describir el comportamiento de la productividad total de los factores de las empresas manufactureras de la región frontera norte de México durante el período 1993-2018. La aproximación metodológica está enfocada en el Residuo de Solow y en los diagramas *Sunrise/Sunset* de Harberger para identificar las contribuciones de cada una de las entidades. Los principales hallazgos de la investigación indican aumentos significativos en las fuentes de crecimiento para la región. Además, el progreso de la misma se encuentra diversificado entre las entidades, siendo la productividad de Nuevo León la que más destaca. Se concluye que la región frontera norte se ha convertido en el mayor polo de generación de empleos del sector manufacturero del país, aunque ha sido limitado en términos de productividad factorial total. Ello hace necesario el desarrollo de políticas intraregionales con medidas específicas que mejoren la productividad agregada en cada estado.

Palabras clave: 1. manufacturas, 2. productividad total de los factores, 3. crecimiento económico regional, 4. frontera norte, 5. México.

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INTRODUCTION

After almost three decades of regional economic development in Mexico, in the face of the challenges brought about by the consolidation of trade integration with the Unites States and given the heterogeneity of results in terms of economic growth patterns (De León Arias, 2019), researching on specific regions such as the northern border is a necessity for the better identification of its economic growth dynamics.

The present article retrieves and updates the current scientific output, presented by De León Arias (2008), regarding the dynamics of the productivity of the Northern Border (NB) over the period from 1970 to 2004. In this article, the period from 2004 to 2018 is addressed, the study disaggregates at federated state level, which allows characterizing the regional economic growth pattern from a study on growth accounting, commonly known as Solow growth model, and the contributions from the NB region by means of Harberger's sunrise/sunset diagrams (1998). Particularly, the goal of the present research is to outline the production performance of the economic activity at Mexico's Northern Border from an analysis of the accounting of factors at manufacturing level over the 1993-2018 period, and several subperiods relevant for the analysis. Moreover, the degree of contribution from each state to the growth of regional productivity is identified resorting to sunrise/sunset diagrams.

The method utilizes Solow's residue to calculate Total Factor Productivity (TFP) by means of a Cobb-Douglas type function with constant returns that establishes the magnitude of the aggregated revenue contained in capital and work to enable the breakdown of the products' growth rate; moreover, it quantifies its growth over time. Adding to the above, Harberger's (1998) sunrise/sunset diagrams indicate the contributions from each of the federated states considering their own growth and contribution to the regional added value. In this way, it is possible to express performance in terms of productivity by state and displaying their contribution to the region.

The document is composed of five sections. In the first, we present the literature, in which De León Arias (2008) refers to the relevance of border regions to better explain the relationship between trade integration and regional economic growth (in the context of the new economic geography), as well as the bases of the so-called growth accounting. In the second section, the sources of growth at the NB region are identified. In the third one, the methodology of growth accounting is presented. In the fourth section, sunrise/sunset diagrams for each of the states comprised in the region are displayed; they will enable us to identify the particular contribution from each state to global regional growth. Finally, the last section presents the conclusions.

LITERATURE REVIEW

The analysis of productivity by means of growth accounting has experienced comprehensive development after the pioneering works by Abramovitz (1986) and Solow (1956), later expanded by Kendrick (1961), and particularly Denison (1962). One of the later development lines was the incorporation of changes in the quality of labor and capital by means of a dual approach, in which

the residual attributed to total factor productivity (TFP) is identified in the growth rates of such factors' prices.[3]

Another aspect analyzed in this method is the incorporation of investments and development expenditures as key determinants of TFP (Griliches, 1973, 1988). From this standpoint, recently, a link between capital accumulation and innovation has been put forward, following neo-Schumpeter's growth models (Aghion & Howitt, 2008). Due to the characteristic low innovation level of Mexican regions, this methodologic line will not be approached in the present article.

TFP Analysis by Region in Other Countries

While an aggregated analysis at the level of a country is relevant, studies have demonstrated wide variations by sectors and regions. As regards the applications of growth accounting by region, we refer a brief listing of recent bibliography we consider outstanding.

A study carried out by Moomaw and Williams (1991) analyzes the TFP of the 48 contiguous U.S. states at the level of manufactures for regions using transversal data. The findings point at the existence of a poor association between variations of TFP growth and that of the regions' production. However, studies on the states reveal a positive relationship between the growth of both variables; that is to say, investments on education and transport infrastructure produce higher factor productivity growth rates.

In this regard, Boisso, Grosskopf, and Hayes (2000) run a regional analysis for the U.S. considering the economic cycles with investment and public infrastructure variables. The authors use productivity growth decomposition in the change of efficiency and technologic innovation by means of Malmquist index.[4] The authors express that productivity decreases over recessions as a result of a fall in efficiency, though at boom periods efficiency leads toward higher productivity. In like manner, they point out that the eastern U.S. region shows a better behavior, as over economic crises it experiences negative effects at a lower proportion than other regions. However, in booming periods this region overcomes others in technologic innovation.

For their part, Ascari and Cosmo (2005) study TFP in 20 Italian regions from 1985-2000 using dynamic panel data from grouped ordinary least squares models, least squares with fictitious variables, and generalized least squares. Among their findings, they point at the disparities between Italian regions, being human capital one of the main determinants of such differences. Likewise, after dividing the Italian regions into two macro-regions (north-south), the duality of regional development is evident.

For their part, Rajiv Kumar and Ajay Kumar (2016) examine TFP in manufactures at regional level for the 15 most relevant states in India over the period from 1982-83 to 2000-01 with the construction of Malmquist index following a linear nonparametric programming. To do so, they

[3] Particularly, see Jorgenson and Griliches (1967), and Harberger (2005); it is an extension and such methodology, we will use in this article.

[4] Malmquist index allows contrasting the productivity of various economies through the estimation of efficiency changes over time on the basis of a production function in relation with labor and capital.

put forward the breakdown of technical progress by means of efficiency and technologic changes with an isoquant that serves as a technologic reference. Likewise, they point at a reduction in regional differences, mainly after the application of a labor reform, though divergences still persist between Indian regions.

As regards regional TFP analysis, Iregui, Melo and Ramírez (2006) focus on Colombian manufacturing firms by economic sector and metropolitan areas over 1975-2000. The authors resort to dynamic panel data, and unit root and Larsson's cointegration tests to ascertain the factors' elasticities. They state that at sector level, the most productive are industries that produce beverages, chemical substances and paper. Similarly, after weighing the regional productivity indexes, Cartagena is the most productive, partly because of the contribution from the sector that produces industrial chemical substances.

For his part, Tello (2012) carried out a study on TFP in Peru via the 24 departments from 1980 to 2015. The TFP analysis is run with a Cobb-Douglas type function based on Solow's residual. Regarding the observed results, it is established that factor productivity behaves decreasingly in all the departments and, at large, in Peruvian economy.

In a research by Delgado and Garrido (2012), the TFP of the Chilean economy is analyzed over the period from 1996 to 2010. Growth accounting is carried out with a more fundamental model, as the amounts of production and stock are resorted to contrasting the specialization indices with regional macro-productivity. By means of the application of growth breakdown, results express a better performance of TFP in the regions with specialized production infrastructure, being Atacama outstanding as it experienced significant productivity increases. Likewise, the authors state the importance of mining as a defining factor to understand the differences in regional productivity.

To sum up, the results of the works presented in this section exhibit persistent interest in identifying TFP for the purpose of explaining regional dynamics, as well as the coexistence of the calculation of TFP, either via the direct application of growth accounting or any econometric methodology. Also, a certain preference, defined by availability, is noticed for the extension of data and growth accounting, which will be applied with some modifications in this article. Moreover, the comparability of results with similar research works is kept, as it is the case of the work by De León Arias (2008).

Total Factor Productivity in the Northern Mexican Regions with Emphasis on the Norther Border

As regards the identification of the regional productivity dynamics in Mexico, following, we describe works in the literature regarding TFP. In this sort of studies, a research by Hernández Laos (1992) stands out as an early contribution from one of the forerunners of this topic in Latin America.

Among the analyses of regional productivity, a region which has been object of particular interest is Mexico's NB. Particularly, De León Arias (2008) ran an analysis of factor productivity at regional level for the 1970-2004 period. Resorting to Solow's residual, the author studied the federated states identified as regions, large cities and NB, and obtained a TFP growth of only 0.08%

for the entire analyzed period. In the face of this, a deceleration in terms of productivity is noticed, with the exception of the subperiod from 1985 to 1993, in which the increase of TFP was 6.72%. Such growth is related to the trade aperture of the Mexican economy in the 1980's decade. Moreover, it indicates that the NB region registers a reduced growth of factor productivity, which is attributed to a limited capability to incorporate technical progress.

In more recent research works, Padilla Hermida and Guzmán Plata (2010) analyze TFP and manufacturing growth in Mexico for the period from 1993 to 2007 by means of a Cobb-Douglas production function with four cross sections, including all the country's federated states. Among their findings, they point out that the growth of national manufacturing production has an effect of 0.36% points on GDP growth, which implies very limited impacts from manufactures on the growth of Mexican economy. The above is supported on low factor productivity growth at regional level as it kept the same conditions as in the initial period, and even show tendencies to diverge in the regions of the country.

For his part, De León Arias (2013) analyzes the TFP of manufactures in Mexican states over 1970-2008 from sunset/sunrise diagrams for the purpose of finding the contribution level from each to employment, capital and product factors. On the basis of his results, the author points at the existence of noticeable differences between Mexican states, being Mexico City[5] one of the "losers" with a negative growth rate of 2.17%. For their part, the "winners" that locate in the north and center of the country, as a set, reach a growth of 2.18%.

In a research developed by Becerril Torres, Díaz Carreno, and Del Moral Barrera (2013), the socioeconomic regions of Mexico are studied over the period 1970-2008, from the measurement of technical changes and efficiency change. To do so, nonparametric techniques are utilized by means of Data Envelopment Analysis (DEA) of Malmquist index, its components and linear programming. Among their main findings, there is a TFP increase in each of the seven analyzed regions, which came from technologic change. Furthermore, this change has produced a displacement of the technological border and an increase in fluctuating intertemporal productivity.

For its part, the study by Atayde Villegas (2016) for the states of Mexico in the period from 1998 to 2013, by means of a TFP breakdown, develops an empirical model that carries out econometric estimations of an aggregated production function by means of the data panel methodology by means of a fixed effects method. Among the results, it is mentioned that the growth of TFP is moderated, as its increase was 1.5% for the entire period, being Mexico City and the states of Nuevo León, Chihuahua, and Veracruz, those with the highest growth rate.

For its part, the Klems model, developed by Instituto Nacional de Estadística y Geografía (Inegi) [National Institute of Statistics and Geography], in which by means of the variables capital (K), labor (L), energy (M) and services (S), it is possible to measure TFP at subsector level of the 77 economic activity groups and the total of the Mexican economy on the basis of Sistema de Cuentas Nacionales [System of National Accounts] with a view to calculating technical progress. In a more recent study, Inegi (2020b) analyzed factor productivity for the 1999-2019 period recording a

[5] Formerly, Distrito Federal (D. F.) [Federal District].

significant volatility in returns each year, therefore, a growth rate of -0.34% in TFP for the entire period.

According to the review of the performance of the Mexican economy TFP, the general findings ratify marked regional differences and limited TFP growth, that is to say, most of the afore cited works exhibits a TFP growth pace under 2% a year, with a clear deceleration over the last 20 years, and so, a reduced dynamism of Mexican manufacturing activities. This was supported by Loría (2009), who states that the Mexican economy has not been able to restore the structure of accumulation, as the differences in terms of productivity have been widened due to poor capital performance and investment. Particularly, in this regard, this result is frequently shared by studies on the growth of productivity in Mexico's economy.

ANALYSIS OF THE SOURCES OF GROWTH

Participation of the NB Region in National Manufacturing Firms

In this section and with a view to contextualizing the analysis of productivity growth in NB, data on its participation in terms of production (gross censual added value) and employment are presented, particularly regarding the added value of the manufacturing sector in Mexico (Table 1). Early in the period, in 1993, the NB region contributed with 23.76% of the production, while in 1998, there was an important increase, as it contributed with 30.84% of the Mexican production. By 2003, the increment persisted as it contributed with 33.11%. In 2008, there was a slight diminution as it contributed with 32.86%; while for 2013, the region collaborated with 35.58%; and finally, in 2018, its contribution was 37.52% of the national total.

Table 1. Value of the NB region production regarding the national total (1993-2018)*

NB Region	1993	1998	2003	2008	2013	2018
Baja California	2.4	4.02	4.12	4.11	3.86	4.68
Coahuila	3.9	5.95	5.26	6.4	8.11	9.2
Chihuahua	3.33	4.82	7.5	5.01	4.25	4.67
Nuevo León	8.78	9.49	9.77	9.8	10.35	11.23
Sonora	2.37	3.33	2.51	3.6	5.06	4.07
Tamaulipas	2.99	3.21	3.95	3.94	3.96	3.67
Regarding the national total	23.76	30.84	33.11	32.86	35.58	37.52

*In percentage.

Source: Own elaboration based on data from Inegi's Economic Censuses (1994, 1999, 2004, 2009, 2014, 2020a).

In the light of these results, it is plain to see that the NB region has grown significantly over the period of study, as presently it is the one that contributes the most to the production of Mexican manufacturing firms. It is worth pointing out that Nuevo León is significantly noticeable, as it records more than 11% of national manufacturing production.

The description of the statistical analysis of production exhibits the great relevance the NB region has and poses important structural changes in Mexican manufacturing, being one of the most noticeable the geographic restructuring of their activities. That is to say, on the basis of the term of study, it may be established that such relocation of manufactures implied the incorporation of new industrial zones, mainly in the localities at the northern border of the country.

METHODOLOGY OF GROWTH ACCOUNTING

As regards the growth accounting methodology utilized in this article, it is necessary to point out that TFP is expressed as the relationship between actual production and the weighed addition of all the factors utilized in the production process. Its goal is to break down changes in production from variations in the amount of inputs and in all the residual factors, as well as technology, in the number of people involved in production, in the use of installed capacity and in the quality of production factors.

To calculate factor productivity, a Cobb-Douglas type function was utilized to allow identifying the relationships generated between production distribution and the variations of labor and capital. The Cobb-Douglas function uses constant scale returns from the characteristics of capital returns (equation 1) and labor returns (equation 2):

$$PMgK*K= \alpha *Y \quad (1)$$

$$PMgL*L= (1- \alpha)*Y \quad (2)$$

where α is a constant between 0 and 1, whose purpose is to measure the contributions of capital in production. That is to say, α limits capital contributions, while 1- α, those of labor. Owing to this, the Cobb-Douglas production function is ascertained by means of the following equation:

$$Y = AK^{\alpha} L^{1-\alpha} \quad (3)$$

in which A refers to a parameter greater than 0, which calculates the productivity of the existing "residual" technology in the economy. The Cobb-Douglas function provides a high substitution degree between capital and labor and allows identifying the magnitude of the aggregated income contained in the capital and labor factors.

In this way, equation 4 shows the coefficients of capital and labor participation. Such estimators weigh the contribution of the two production factors, which allows identifying the participation coefficient of employment (1- α) obtained by means of the equation below:

$$Coefficient = \left[\frac{\left(\frac{Final\ income}{Final\ product}\right)+\left(\frac{Initial\ income}{Final\ product}\right)}{2}\right] \quad (4)$$

The coefficient is defined as the mean of the addition of the quotients of the initial income between the initial product and the final income between the final product. To analyze the evolution of the sources of growth of the manufacturing sector at the NB region over the 1993-2018 period, TFP estimations were used for the purpose of verifying the existence or not of variations in the region's productive activity. Consequently, the calculation of TFP contemplates the breakdown of

the growth rate between the addition of the rates of capital and labor growth, by means of weighing each factor as a result of its contribution to Gross Added Value (GAV) and its factor productivity. The estimator of TFP is referred by means of the following equation:

$$gTFP = \tilde{A} = gQ - (\alpha gK + (1- \alpha)gL) \qquad (5)$$

where *g*TFP is the rate of the growth of TFP; *g*Q is the growth of product; *gK* is capital growth; *g*L is employment increase; while α is the contribution from capital to the product. TFP estimations were carried out for the NB states (Baja California, Chihuahua, Coahuila, Nuevo León, Sonora, and Tamaulipas) from 1993 to 2018, as for the subperiods 1993-1998, 1999-2003, 2004-2008, 2009-2013, and 2014-2018, for the purpose of observing the growth dynamic of each of the factors and the product of the region as a whole.

It is worth pointing out that data on manufacture were recorded in Inegi's Economic Censuses in the years 1994, 1999, 2004, 2009, 2014, and 2020. The utilized variables were: people employed by the end of year; Gross Census Added Value; wages and net fixed assets. Data on the last three variables were deflated with the National Consumer Price Index (base 2018), as there is no such index at state or regional level. Total observations in NB states reach 360 cases.

Even if at present, methodologies such as the Klems model (Inegi, 2020b) have been implemented, it is important to point out that by considering the space and time of the present research, on occasion there are comparability problems between censuses by period. Owing to this, in the article, Solow's residue is utilized with a Cobb-Douglas type function as in other national and international studies (Tello, 2012; Padilla & Guzmán, 2010).

Total Factor Productivity of Mexican Manufactures

Table 2 shows data gathered by the study on the sources of growth of Mexican manufactures for 1993-2018. As regards the 1993-1998 subperiod, the following results are displayed. As of the coming into force of NAFTA, large capital investments are registered and with this, a noticeable increase in employment and production. However, these favorable events did not turn into factor productivity for there are negative returns in the period.

Table 2. Growth rate of national manufactures (1993-2018)*

Factor	1993-1998	1999-2003	2004-2008	2009-2013	2014-2018	1993-2018
Production	2.52	1.77	5.29	-0.89	8.52	3.39
Employment	1.87	-0.51	0.19	0.19	2.35	0.85
Capital	3.21	-0.3	0.33	1.52	1.8	1.31
TFP	-2.54	2.58	4.77	-2.60	4.35	1.23

*In percentage.

Source: Own elaboration based on data from Economic Censuses (Inegi, 1994, 1999, 2004, 2009, 2014, 2020a).

As regards the 1999-2003 subperiod, national manufactures show drops in terms of employment and capital, and increases in production and TFP. As regards the 2004-2008 subperiod, similar

patterns to the previous subperiod are noticed, as modest capital and employment levels are registered, though with higher returns in production and TFP.

In the following subperiod (2009-2013), a diminution in production and employment paralysis are experienced, which produced a negative growth rate in the factor productivity that concurred with the 2009 Great Recession. Mendoza Cota (2010) supports the above, by pointing out that the NB states registered dramatic drops in manufactures, with a heavier impact on the automotive sector and electronic industry, propitiating the closure of a large number of firms. For the 2014-2018 subperiod, there was a significant increase in the factor productivity of sources of employment, production and capital, and with this, an economic recovery process of Mexican manufactures.

For its part, the period from 1993-2018 shows moderate rate growths for each of the factors. As regards employment, important increases were noticed in the periods 1993-1998 and 2014-2018, though in other, a marked deceleration was noticed; even in the period from 1999 to 2003, there was a downturn. The case of production showed a very similar pattern only because in the periods 2004-2008 and 2014-2018 there was a noticeable growth, nevertheless, the rest of growth rates were low. These data display noticeable differences in production performance, since 2004-2008 and 2014-2018 positive results were obtained, while in 1993-1998 and 2009-2013, growth rates were negative, which may be associated with the impact of economic crises[6] on Mexican manufactures.

Total factor Productivity of the Northern Border Region

The sources of growth of the NB region for 1993-2018 and intermediate periods are displayed in Table 3. From the methodology derived from equation 5, in the first subperiod, 1993-1998, the performance of the employment, production and capital variables were relevant as they showed significant growths. However, this did not become an important TFP growth rate, which may be explained, as expressed by Carbajal Suárez, Almonte and Mejía Reyes (2016), as an effect from the trade agreement with the U.S. and Canada, which favored the increase of foreign direct investment and the establishment of new firms in localities close to the U.S., which brought about important increases in production and employment.

As regards the subperiod 1999-2003, there were employment contraction and increases in production and capital which turned into a TFP increase. Such tendency was ratified during the following subperiod, 2004-2008, as they showed similar results. This may be understood because of the economic recession experienced by the country from the effects caused by the 2001 terrorist attacks on the U.S., and as a consequence of the closure of manufactures in places close to the border.

[6] The Tequila Effect in 1994-1995, and the Great Depression 2008-2009.

Table 3. Growth rates for the northern border region (1993-2018)*

State	1993-1998	1999-2003	2004-2008	2009-2013	2014-2018	1993-2018
Production	8.01	3.23	5.14	0.7	9.67	5.3
Employment	3.52	-0.25	-0.04	0.52	3	1.39
Capital	3.62	0.75	0.93	2.27	1.26	1.77
TFP	0.87	2.73	4.25	-2.09	5.41	2.14

*In percentage.

Source: Own elaboration based on data from Inegi's Economic Censuses (1994, 1999, 2004, 2009, 2014, 2020a).

However, the subperiod 2009-2013 recorded a negative growth rate for TFP and minimal increases in employment and production. The figures may be conditioned by a pro-cyclical behavior, as proposed by Jiménez and Marchetti (2002), as they point out that factor productivity has a positive relationship with economic fluctuations in the country. For its part, during the subperiod 2014-2018, there was an important recovery in the sources of growth in the region and even, it is the term with the most dynamism. The great performance of the NB region is indeed evident, which corroborated its importance in the growth of Mexican manufacturing firms.

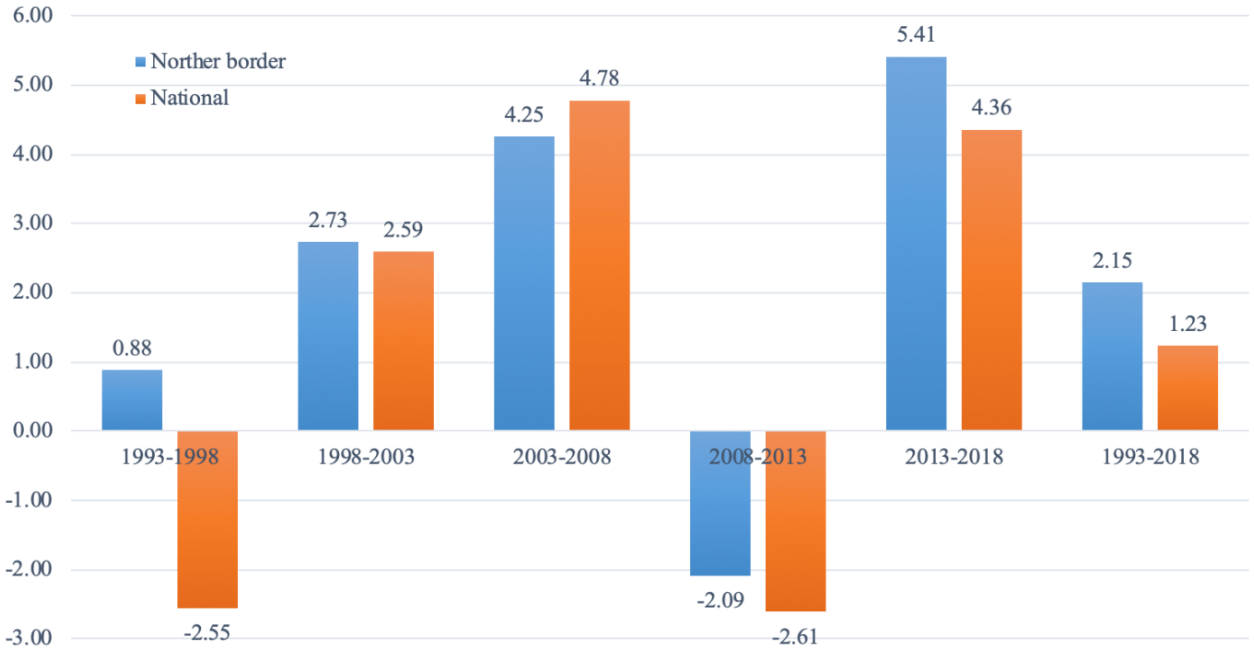
Finally, for the entire period from 1993 to 2018, the growth sources offer positive results, it is a symptom of the region's good performance. Data accounted for important growth in production and employment. As regards TFP, there was an annual growth rate of 2.15%. Owing to this, it is worth emphasizing the significant increment in production supported on the extensive use of employment, a lower capital contribution and a suitable growth of factor productivity.

The results demonstrate that, once NAFTA came into force, there was an important increase in employment and production variables. However, after this, a deceleration was noticed in TFP to reach a decrease due to the 2008 Global Financial Crisis. In the final years of the analysis, there were encouraging results in the performance of growth sources in the region. By and large, results point at a significant boost in terms of employment in NB region, though the pending task is to translate them into important increments in productivity to accelerate the economic development of the country.

Comparison of the TFP of National and NB Manufacturing Firms

Once factor production analysis was developed, Graph 1 shows the performance of factor productivity at NB and the national total over the study period, 1993-2018, divided into five subperiods. TFP shows similar growth tendencies for national and NB manufactures, making its importance for the development of the country in this sector clear. A good performance of the NB is noticed as, with the exception of the period from 2009-2013, positive TFP growth rates are registered.

Graph 1. Total factor productivity at the northern border region and national level (1993-2018)*



*Growth rates.

Source: Own elaboration based on Inegi's Economic Censuses (1994,1999, 2004, 2009, 2014, 2020a).

Adding to the above, by observing the evolution over the entire period, it is noticed that the NB region registered an annual mean TFP growth of 2.15%, while the national annual mean had a growth rate of 1.23%. This might be explained by the dynamism of the NB region in terms of employment and production, while the national performance of manufactures was lower and unstable; mainly in central and southern States over the study period.

Once the statistical-descriptive analysis was carried out from the production dynamics of manufactures and with the results in terms of employment and production, by means of the TFP tool, it is attributed that the regional adjustment in the country due to the relocation of industrial activities, particularly the geographic restructuring of manufacturing firms, has promoted a change in the supremacy of activities and made the NB region turn into a significant employment hub for Mexican manufacturing firms.

SUNRISE/SUNSET DIAGRAMS APPLIED TO NORTHERN BORDER'S TFP

A number of studies on economic growth focus on demonstrating the existence of disparities or not in the growth of economies over time. In this regard, Harberger (1998) approaches an asymmetric process that takes place in the economic growth of the countries and involves several factors, among which noticeable are: i) contributions from the sectors that increase factor productivity concentrate in a handful of industries; ii) in an economy with TFP growth, there are

winners and losers, the latter usually largely reflect TFP performance; and iii) it is not possible to point out a prevalence of one economy or state over the various periods.

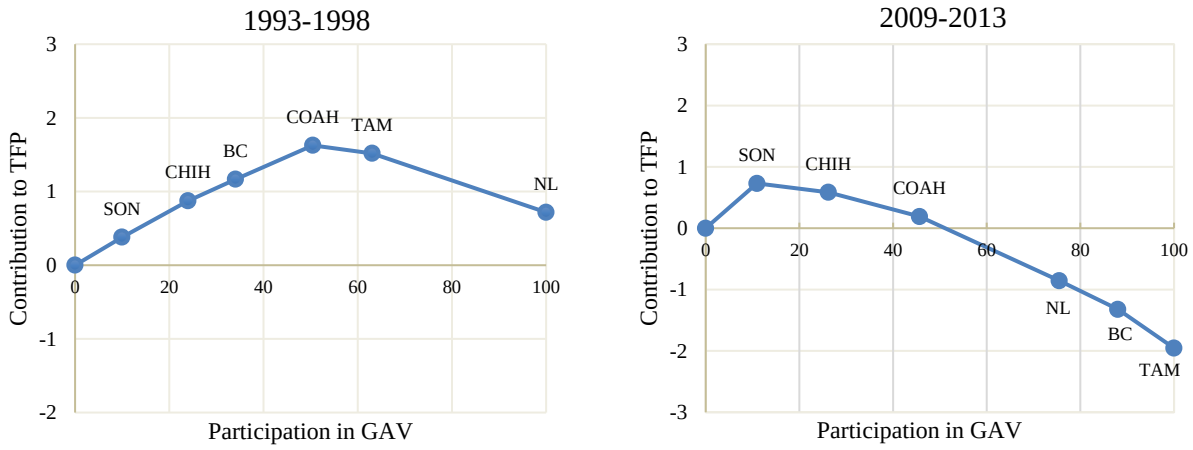
In this sense, Howitt (2015) states that the growth of TFP, in addition to being unequal, is unpredictable, as it depends on the distribution of technologic change, which is even harder to forecast. In the face of this scenario, it is obvious to point that differences in the growth paces of activity propitiate winning and losing states, because resources change and because firms may be located in areas far from places where production generates higher revenues.

The study carried out by Harberger (1998) referring to sunset/sunrise diagrams is considered the starting point to ascertain the growth of production factors between sectors in an economy because it allows representing the TFP distribution in a graph by organizing the contributions from each of the region's states. That is, there is a sunrise diagram when the rate of the accumulated factor productivity is positive. While a sunset diagram represents a negative TFP growth rate. In this way, the methodology of sunrise/sunset diagrams is as follows:

1. The states are listed in decreasing order, according to their productivity performance.
2. A column is produced to present the contribution to GAV per state.
3. The contribution of factor productivity is multiplied by their respective participation in GAV.
4. The accumulated value of TFP contributions is calculated.
5. The participation in GAV is generated in an accumulated manner.

Graph 2 presents the sunrise/sunset diagrams at the NB region in five-year periods from 1993 to 2018. As regards the subperiod 1993-1998, there was a TFP growth rate of 0.72%. The states with positive rates were Sonora, Chihuahua, Baja California, and Coahuila, while the losing states were Tamaulipas and Nuevo León.

Graph 2. Sunrise/Sunset diagrams of TFP growth at NB region (1993-2018)



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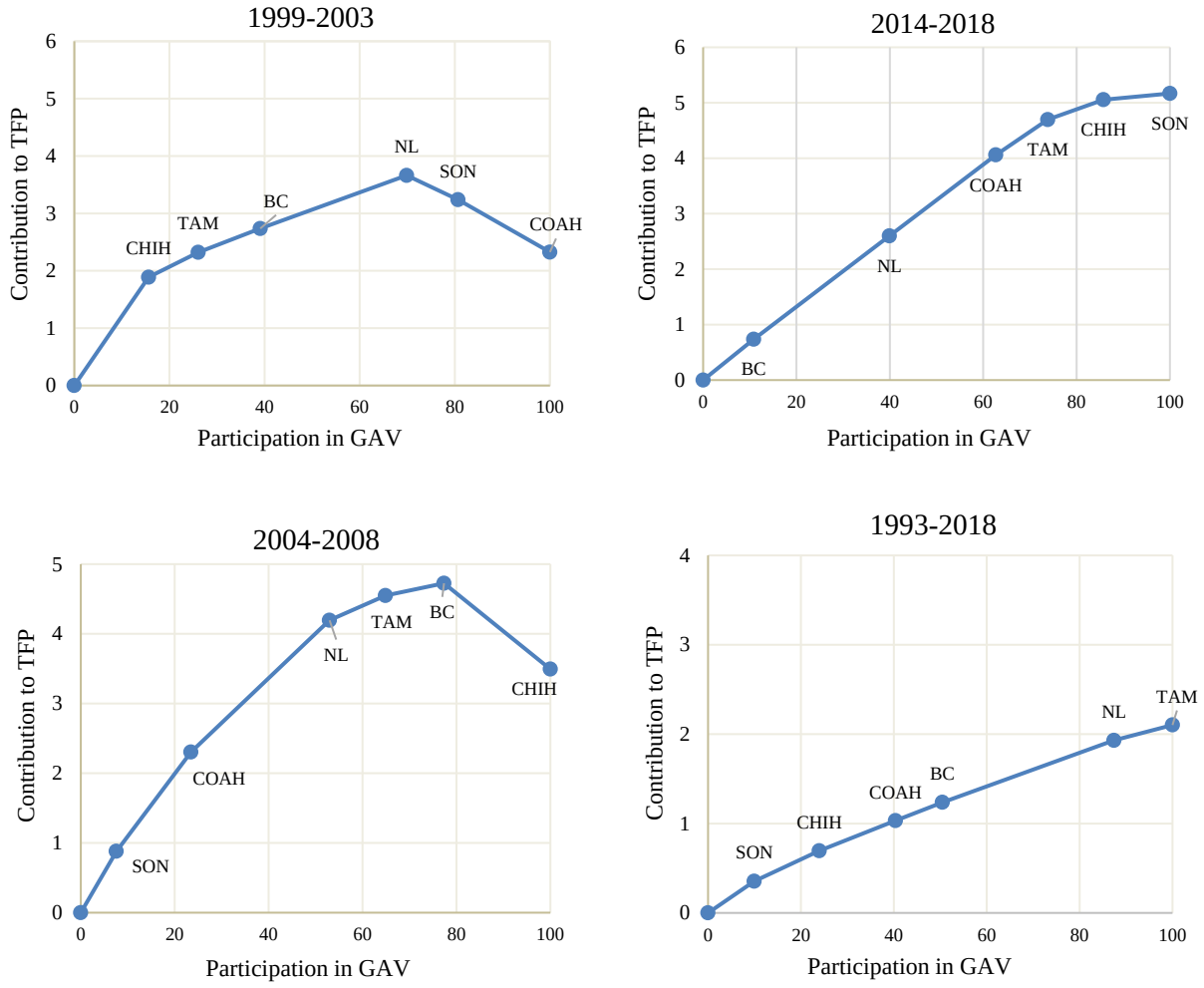

Source: Own elaboration based on Inegi's Economic Censuses (1994, 1999, 2004, 2009, 2014, 2020a).

Over the period from 1999 to 2003, the regions' performance experienced an increase in TFP of 2.33% a year because four states—Chihuahua, Tamaulipas, Baja California, and Nuevo León—significantly increased their productivity, which entailed a reduction of actual costs, and so, a higher efficiency in production processes. Such states as a set contributed with 70% of the region's total production. For their part, the states of Sonora and Coahuila had negative returns.

For the subperiod 2004-2008, there was a TFP growth of 3.49% in the region's total. It is important to point out that five states in the region experienced increases in factor productivity, being Nuevo León and Coahuila the ones with the most contributions. Both states, as a set, produced 45% of the region's production, which is a symptom of a good performance over the period.

For its part, in the 2004-2013 period, there is a noticeable decrease in the manufacturing firms in the region, as they have negative returns for TFP at a rate of -1.95%. From the financial crisis that started in the U.S. with effects on the global economy, the region experienced a fall in labor and also closing firms, mainly in maquiladoras, which reduced production and employment. In point of fact, with the exception of Sonora, the rest of the states had negative growth rates.

Over the 2014-2018 period, there was a noticeable recovery for the region as it had a TFP growth rate of 5.17%. All the states had increases in productivity, being noticeable Nuevo León with a contribution of 1.86 points and Coahuila, with 1.46 TFP points, reaching 64% of factor productivity as a set, which is an indication of their importance in the region's development. Finally, for the entire period 1993-2018, the region registered a TFP growth rate of 2.1%. The state with the most contribution was Nuevo León, with 0.69 points, which is 33% of the region's total. The rest of contributions were low: Sonora, 0.35 points; Chihuahua, 0.34; and, Coahuila, 0.33, in the regional total. Owing to this, the performance of factor productivity was barely above two units within the entire period.

It is evident that the process of trade aperture in the middle of the 1980's and NAFTA's coming into force in 1994 propitiated a spatial reorganization of industrial activities, as the main manufacturing firms moved toward the NB for the purpose of creating agglomeration economies and reducing transportation costs (Valdivia López, 2008). This is supported by Díaz-Bautista, Avilés and Rosas Chimal (2003) by pointing out that the NB became an important area for the growth of the country due to the relevance of its industrial dynamic linked to foreign investment in the region.

In this regard, Calderón Villareal and Martínez Morales (2005) express that a set of processes have combined and allowed the restructuring of manufacturing activities: firstly, globalization favored trade aperture and with this the relocation of firms in cities at the border with the U.S.; second, the transformation of traditional manufacturing activities; and in the third place, the disaggregation of the activities of former industrial centers in Mexico, specifically the decentralization of manufacturing firms in Mexico City.

CONCLUSIONS

On the basis of the regional economy area, the present article analyzes and describes the dynamic of Mexican manufacturing firms through the study of the northern border region. Results are analyzed from two standpoints; performance in terms of factor productivity in the region from 1993 to 2018, and the particular performance of each of the border states according to their contribution to the NB region.

In this regard, the dynamism of border states is evident, as their performance allows verifying their relevance and transcendence for Mexican manufacturing firms. The results denote a great boost for the region's manufacturing firms, as regards production and employment, accounting for 37.4% of the population employed, and slightly more than 37.5% of the national total censual gross added value. This means that the NB region has become a significant employment hub for Mexican manufacturing firms.

In like manner, with the trade aperture in the country and NAFTA coming into force, Mexican manufacturing activities reconfigured and brought about noticeable changes in the region's growth. In this new stage, NB states have been benefited by the arrival of a large number of maquilas, becoming the region that holds supremacy in terms of employment and production of Mexican manufacturing enterprises.

The analysis applied from sunrise/sunset diagrams allowed describing the performance of each of the states distinguishing those that boosted the growth of TFP regarding those that reduced it, and understanding the spatial dynamics generated in the region. In this regard, the northern border had good results, as all its states registered positive growth rates and very similar contributions to TFP over the entire period, though the states of Nuevo León and Coahuila were considered "winners" for they presented the highest contributions to the increase of factor productivity. Owing to this, based on the information in the diagrams, the continuous progress displayed by the NB region was verified.

In terms of TFP, the obtained results allow making two major considerations. On one side, they verify that the northern border region has turned into the largest employment hub in the country, as it displays a noticeable growth in creation of job posts. And, on the other, such increase in the region has been insufficient to boost a larger growth of Mexican manufacturing firms, that is to say, the boost to the region has not become greater dynamism of factor productivity at national level. Owing to this, it is fundamental to develop regional policies that improve productivity and promote the strengthening and growth of Mexican manufacturing firms.

Translation: Luis Cejudo-Espinosa.

REFERENCES

Abramovitz, M. (1986). Catching up, forging ahead, and falling behind. *The Journal of Economic History*, *46*(2), 385-406.

Aghion, P. & Howitt, P. (2008). *The economics of growth*. Cambridge: MIT Press.

Ascari, G. & Cosmo, V. (2005). Determinants of total factor productivity in the Italian regions. *Scienze Regionali*, 27-49.

Atayde Villegas, R. (2016). Análisis del crecimiento de la productividad total de los factores de los estados de México 1998-2013. In *El desarrollo regional frente al cambio ambiental global y la transición hacia la sustentabilidad* (pp. 1-22). Mexico City: Asociación Mexicana de Ciencias para el Desarrollo Regional.

Becerril Torres, O., Díaz Carreno, M., & Del Moral Barrera, L. (2013). Frontera tecnológica y productividad total de los factores de las regiones de México. *Región y Sociedad*, *25*(57), 5-26.

Boisso, D., Grosskopf, S., & Hayes, K. (2000). Productivity and efficiency in the US: Effects of business cycles and public capital. *Regional Science and Urban Economics, 30*(6), 663-681. https://doi.org/10.1016/S0166-0462(00)00046-6

Calderón Villareal, C. & Martínez Morales, G. (2005). La ley de Verdoom y la industria manufacturera regional en México en la era del TLCAN. *Frontera Norte*, *17*(34), 103-137.

Carbajal Suárez, Y., Almonte, L. de J., & Mejía Reyes, P. (2016). La manufactura y la industria automotriz en cuatro regiones de México. Un análisis de su dinámica de crecimiento, 1980-2014. *Economía: Teoría y Práctica*, (45), 39-66.

De León Arias, A. (2008). Cambio regional del empleo y productividad manufacturera en México: El caso de la frontera norte y las grandes ciudades: 1970-2004. *Frontera Norte*, *20*(40), 79-103.

De León Arias, A. (2013). El desempeño productivo regional de las manufacturas mexicanas. Un análisis de contabilidad del crecimiento en las entidades federativas (1970-2008). Guadalajara: Universidad de Guadalajara.

De León Arias, A. (2019). El desarrollo regional en México: Tratado de Libre Comercio de América del Norte, exportaciones, modelos de innovación, multinacionales e inversión pública. Guadalajara: Universidad de Guadalajara.

Delgado, C. & Garrido, N. (2012). Contabilidad del crecimiento en las regiones de Chile: 1987-2009. Antofagasta: Universidad Católica del Norte.

Denison, E. (1962). *The sources of economic growth in the United States and the alternatives before us.* Washington, D.C.: Brookings Institutions.

Díaz-Bautista, A., Aviles, J., & Rosas Chimal, M. (2003). Desarrollo económico de la frontera norte de México. *Observatorio de la Economía Latinoamericana*. Retrieved from https://www.eumed.net/cursecon/ecolat/mx/Diaz-AvilesChimal.pdf

Griliches, Z. (1973). Research Expenditures and Growth Accounting. In B. R. Williams (Ed.), *Science and technology in economic growth* (pp. 59-95). New York: International Economic Association.

Griliches, Z. (1988). Productivity puzzles and R&D: another nonexplanation. *Journal of Economic Perspectives*, *2*(4), 9-21. https://doi.org/10.1257/jep.2.4.9

Harberger, A. (1998). A vision of the growth process. *The American Economic Review*, *88*(1), 1-32.

Harberger, A. (2005). *On the process of growth and economic policy in developing countries*. Los Angeles: Bureau for Policy and Program Coordination.

Hernández Laos, E. (1992). *Evolución de la productividad total de los factores en la economía mexicana (1970-1989).* Mexico City: Secretaría del Trabajo y Previsión Social.

Howitt, P. (2015). *Mushrooms and yeast: the implications of technological progress for Canada's economic growth*. Toronto: Howe Institute. Retrieved from https://www.cdhowe.org/sites/default/files/attachments/research_papers/mixed/Commentary_433.pdf

Instituto Nacional de Estadística y Geografía (Inegi). (1994). Censos Económicos 1993. Aguascalientes: Inegi.

Instituto Nacional de Estadística y Geografía (Inegi) (1999). Censos Económicos 1998. Aguascalientes: Inegi.

Instituto Nacional de Estadística y Geografía (Inegi). (2004). Censos Económicos 2003. Aguascalientes: Inegi.

Instituto Nacional de Estadística y Geografía (Inegi). (2009). Censos Económicos 2008. Aguascalientes: Inegi.

Instituto Nacional de Estadística y Geografía (Inegi). (2014). Censos Económicos 2013. Aguascalientes: Inegi.

Instituto Nacional de Estadística y Geografía (Inegi). (2020a). Censos Económicos 2018. Aguascalientes: Inegi.

Instituto Nacional de Estadística y Geografía (Inegi). (2020b). Productividad total de los factores (PTF) Modelo Klems. Serie anual 1990-2019 (Press release no. 651/20). Retrieved from https://www.inegi.org.mx/contenidos/saladeprensa/boletines/2020/StmaCntaNal/PTFK2019.pdf

Iregui, A., Melo, L., & Ramírez, M. (2006). Productividad regional y sectorial en Colombia: Análisis utilizando datos de panel, *Ensayos sobre Política Económica*, *25*(53), 18-65.

Jiménez, M. & Marchetti, D. (2002). Interpreting the procyclical productivity of manufacturing sectors: Can we really rule out external effects? *Applied Economics*, *34*(7), 805-817.

Jorgenson, D. & Griliches, Z. (1967). The Explanation of Productivity Change. *The Review of Economic Studies*, *34*(3), 249-283. https://doi.org/10.2307/2296675

Kendrick, J. (1961). *Productivity Trends in the United States*. New Jersey: Princeton University Press. Retrieved from http://pombo.free.fr/kendrick1961.pdf

Kumar, R. & Kumar, A. (2016). Tendencias emergentes en la manufactura mundial y los retos para India. In C. Denzin & C. Cabrera (Eds.), *Nuevos enfoques para el desarrollo productivo: Estado, sustentabilidad y política industrial* (pp. 202-235). Mexico City: Editorial Friedrich Ebert Stiftung.

Loría, E. (2009). Sobre el lento crecimiento económico de México: Una explicación estructural. *Investigación Económica*, *68*(270), 37-68.

Mendoza Cota, J. (2010). El comportamiento de la industria manufacturera de México ante la recesión económica de EUA. *Revista de Economía*, *27*(75), 9-35.

Moomaw, R. & Williams, M. (1991). Total Factor Productivity Growth in Manufacturing Further Evidence from the States. *Journal of Regional Science*, *31*(1), 17-34. https://doi.org/10.1111/j.1467-9787.1991.tb00128.x

Padilla Hermida, R. & Guzmán Plata, M. (2010). Productividad total de los factores y crecimiento manufacturero en México: Un análisis regional, 1993-2007. *Análisis Económico*, *25*(59), 155-178.

Solow, R. (1956). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, *70*(1), 65-94. Retrieved from http://piketty.pse.ens.fr/files/Solow1956.pdf

Tello, M. (2012). Productividad Total Factorial en el sector manufacturero del Perú: 2002-2007. *Economía*, *35*(70), 103-141.

Valdivia López, M. (2008). Desigualdad regional en el centro de México. Una exploración espacial de la productividad en el nivel municipal durante el período 1988-2003. *Investigaciones Regionales*, (13), 5-34.