Análisis Económico
Núm. 79, vol. XXXII
Primer cuatrimestre de 2017

Total Factor Productivity (TFP) in Manufacturing and Economic Growth in Mexico

(La Productividad total de los factores (TFP) en las manufacturas y crecimiento económico en México)

(Recibido: 22/junio/2016 –Aceptado: 16/noviembre/2016)

Alejandro Díaz Bautista[*]

Abstract

The present study presents a model and estimates Mexico's regional total factor productivity (TFP) that accounts for the economic performance of the country since the 1980's. The findings raise a debate of Mexican productivity over time. One of them is that different measures of output and productivity, leads to different conclusions about productivity at the regional and national level in Mexico.

Keywords: Regional Economic Growth, Total Factor Productivity, Manufacturing, Mexico, Latin America.
Jel classification: D24, L60, O40, O47, R11.

Resumen

El presente estudio presenta un modelo y las estimaciones de la productividad total factorial (PTF) a nivel regional en México, lo que nos ofrece una explicación del desempeño

[*] Alejandro Díaz-Bautista obtained his Ph.D. in Economics at the University of California, Irvine. He is Professor of Economics and Researcher at COLEF. Professor Díaz-Bautista has also been a research fellow and guest scholar at the Center for U.S.-Mexican Studies, UCSD. He has also been a member of the United States - Mexico Border Governors Council of Economic Advisers. Email: <adiazbau@gmail.com>.

económico del país desde los años ochenta. Los resultados plantean un debate sobre las medidas de la productividad mexicana en el tiempo. Dependiendo de las diferentes medidas de producción y de productividad, obtendremos diferentes conclusiones acerca de la productividad a nivel regional y nacional en México.

Palabras clave: Crecimiento económico regional, Productividad total de los factores, Manufacturas, México, América Latina.
Clasificación JEL: D24, L60, O40, O47, R11.

1. Introduction

Economic growth is a major country objective all over the world, and it´s always measured by the indicator economic growth rate. However, this indicator does not describe real economic productivity well. It is widely accepted that productivity is a key performance benchmark. Rising productivity is related to increased profitability, lower costs and sustained competitiveness. The most widely used productivity indicator for firms is labor productivity, such as units of output or value added per worker. However, this measure has serious shortcomings. The main one is that it fails to show why labor productivity has risen in most countries. Consider, for instance, productivity among maquiladoras and high tech manufacturing industry in Mexico. Value added per worker approximately rose by 3.5 per cent annually, during the second half of the 1980's and 1990's. In contrast, overall labor productivity in Mexico rose by less than half that rate. But why did labor productivity in some manufacturing industries outpace that in the overall economy? A possible explanation for the increase in productivity would be economies of scale (in part due to downsizing and improved efficiency) and large investments in maquiladoras and information technology.

Another possible explanation of why productivity rose lies in the seminal research of Nobel Laureate Robert Solow. In his classic paper, Solow (1957) showed how technical progress could be measured by using a production function. In his method, the change in labor productivity was caused by two separate factors: a technical change factor such as improvements in knowledge, and capital deepening. While a technical change factor could not be directly measured, it could be shown as a residual, by subtracting the contribution of capital deepening from the overall change in labor productivity. Solow (1957) found that a majority of nations' economic growth was attributable to technical change, or total factor productivity growth, which he proposed measuring as a residual, based on a production function approach.

Productivity is the cornerstone of economic growth. The average person in Mexico City is richer than his ancestors and than the average person in Chiapas Mexico primarily because of productivity. Productivity also affects our competitive position so the more productive we are, the better we are able to compete on world markets. In short, productivity is the source of the high standard of living enjoyed by the industrial economies relative to the third world or to the same economies fifty or one hundred years ago.

The present study concentrates in the manufacturing sector and its impact in the Mexican Economy. The manufacturing industry had an average rate of growth of 7% between 1960 and 1981, while agriculture grew only at 3.3% during the period. This changed the structure of the whole Mexican economy to a more industrialized economy. By 1980, the share of agriculture in GDP was only 9%, while industry and services represented 57.2 percent. In the late 1980s, the manufacturing sector began to recover. In 1988 manufacturing output grew by a modest 4 percent. After expanding a robust 7 percent in 1989, manufacturing output steadily slowed. Manufacturing grew by only 2 percent in 1992, as a result of weak export growth and falling domestic demand. After contracting by 2 percent in 1993, manufacturing output expanded by 4 percent in 1994. The most dynamic manufacturing subsectors in 1994 were metal products, machinery, and equipment followed by basic metals industries with a 9 percent growth. In 1994 the manufacturing sector accounted for 20 percent of the country's total GDP and employed about 20 percent of all Mexican workers.

By the late 1980s, more than two-thirds of all foreign investment in Mexico was concentrated in maquiladora economic zones near the United States border. In 1965 the government began to encourage the establishment of maquiladora plants in border areas to take advantage of a United States customs regulation that limited the duty on imported goods assembled abroad from United States components to the value added in the manufacturing process. The maquiladora zones offered foreign investors both proximity to the United States market and low labor costs and wages. Most maquiladora plants were established in or near the twelve main cities along Mexico's northern border. Some of these enterprises had counterpart plants just across the United States border, while others drew components from the United States interior or from other countries for assembly in Mexico and then to re-export goods.

It has been acknowledged that the recent regional economic change in Mexico can be described as one where economic activity increases in the northern states and decreases in the largest cities. De Leon (1995) identifies and analyzes the growth patterns of the regional manufacturing for the period 1970-1993, and explores the implications of this regional and state change on the manufacturing productivity growth in Mexico.

In the present study, a model is presented and the empirical analysis of manufacturing output is expanded by regions and states for the period 1985 to1998. The study presents an analysis of manufacturing productivity growth by regions and at the national level, based on total factor productivity (TFP). The implications on the productivity performance of the recent regional and national change in the

Mexican manufacturing productivity growth are presented, and some explanations are given for the observed pattern of productivity growth.

2. The Model of Productivity in Mexico

This section is dedicated to defining and measuring productivity, and using a theoretical framework to determine the sources of economic growth.

Productivity is basically a ratio index of output (Q) to input (X).

$$\text{Productivity} = Q/X \tag{1}$$

Productivity can be measured at various levels, like at the economy, industry, company and operational level. At the economy level, the Gross Domestic Product (GDP) measures output. At the industry and company levels, a commonly used measure is value added. At the operational level, where products or services are homogeneous, output measures can be in physical terms, such as the actual number of goods (e.g. televisions, calculators, etc.) produced. The common input measures are number of workers, hours worked and fixed assets.

What is the role of productivity improvement in sustaining economic growth? It is a widely recognized principle that economic growth, no matter how impressive, will not be sustainable without improvements in productivity. That is why Mexico should make productivity growth an important cornerstone of its economic policy.

TFP measures an economy's efficiency, and can be considered a proxy for measuring innovation in an economy. When a new general-purpose technology arrives, TFP growth can slow down. When this happens, it's difficult to increase wealth or improve the income of citizens. But if the new general-purpose technology is properly exploited, it should eventually lead to increased TFP growth and a corresponding rise in standards of living, including increases in salary levels.

TFP measures the efficiency and effectiveness with which both labor and capital resources are used to produce output. In other words, TFP means making smarter and better use of the labor and capital resources available. A host of causes, which interact with one another in subtle ways, determines TFP. Key causal factors include changes in the quality of labor or the improvement in the variables that affect the productive capacity of workers. One major component of labor quality is human capital investment, mainly in education and skills upgrading which is a key determinant of productivity.

Industries in Mexico may be roughly divided into traditional and modern industries. The output of a traditional industry grows rather slowly (one to several percent per year); its typical representative is agriculture or food production. A modern industry in Mexico grows rapidly and its typical representative is computer manufacture of the Maquiladora Industry. The aggregate growth rate of a national economy depends on the respective proportion of rapidly growing industries and slowly growing industries in the whole economy. In this aspect, the prices play a key role.

As higher TFP means higher productivity, and hence more output for Mexico, it will ultimately lead to more rewards for everyone. For manufacturing industries, better TFP performance means higher profitability. Larger profits make possible reinvestment and further expansion of business. For employees, the rewards take the form of higher wages and bonuses, more benefits, better work environment and job security. Above all, higher TFP gives Mexico the means to enjoy a higher standard of living.

The central feature of any economy is that economic agents take factor inputs such as labor, capital, and raw materials, and how they convert them into useful products. We call this relation between factor inputs and output a production function. Thus we might write:

$$Y = AF\,(K,L) \tag{2}$$

where Y is output (real GNP), K is the stock of physical capital (plant and equipment), and L is labor (the number and hours of people working). The letter A measures what we will call productivity. A higher value of A means that the same inputs lead to more output. We can refer to A sometimes as total factor productivity, to distinguish it from average labor productivity, Y/L. Some of the growth in the Mexican economy is due to increases in A. Technological progress can be thought of as increases in A, or the invention of the new technology. The skill level of the labor force is another thing that might be incorporated in A. The economic and legal environment might also play a role in aggregate productivity. Most economists think that competitive markets play an important role in allocating resources in an efficient manner, and this kind of thinking is behind many of the changes in the Mexican regions. This function shows that we get higher output for three reasons: because more people are working (higher L), because they have more equipment to work with (higher K), or because capital and labor are used more productively (higher A, a catch all category).

Solow (1957) set up the grounds for growth accounting. A growth accounting exercise is intended to break down the growth of output into the growth of the factors of production, capital and labor, and the growth of the efficiency in the utilization of these factors. The measure of this efficiency is usually referred to as Total Factor Productivity (TFP). For policy purposes it may matter whether output growth stems from factor accumulation or from increases in TFP.

3. Regional TFP Model and Framework

Productivity refers to the quantity of outputs obtained from a given quantity of inputs. Productivity change refers to a shift in this relationship. This shift can obviously be either positive or negative, as it can either increase or decrease the volume of outputs obtained from a given level of inputs. Technical change is defined as any shift in the production frontier. If we let t denote a technology index, then the production frontier can be written as:

$$y = f(x, t) \tag{3}$$

Technical change is then defined as a change in the technology index t which affects the relationship between inputs x and output y. Given a change in the technology index t from t_1 to t_2, technical change is said to take place if $\partial f/\partial t \neq 0$ in (3). Assuming $t_2 > t_1$, technical change is called technical progress if $\partial f/\partial t > 0$. For example, if technological change allows to produce more output y with the same quantity of inputs x. Alternatively, given $t_2 > t_1$, technical change is called technical regress if $\partial f/\partial t < 0$, where technological change implies that less output y can be produced with the same quantity of inputs x.

The rate of technical change is defined as follows:

$$[\partial f(x,t)/\partial t] / y \equiv \partial \ln f(x,t)/\partial t \tag{4}$$

The rate of technical change measures the relative change in output y due to the partial effect of the technology index t.

The rate of technical change can be measured from the production function, by estimating $y = f(x, t)$ and deriving the value of $[\partial \ln f(x,t)/\partial t]$ from the regression equation.

The rate of technical change can also be measured from the cost function, by estimating the cost function $C(r, y, t)$, where $C(r, y, t) = \text{Min}_x [r'x\text{: } y = f(x, t)]$. Using the envelop theorem, note that $\partial C(r, y, t)/\partial t = -[\partial C(r, y, t)/\partial y]\ [\partial f(x, t)/\partial t]$. It follows that the rate of technical change can be measured from the cost function as follows:

$$\partial \ln f(x, t)/\partial t = [\partial f(x, t)/\partial t]/y = -[\partial C(r, y, t)/\partial t]/[y\ \partial C(r, y, t)/\partial y] \tag{5}$$

$$= -[\partial \ln C(r, y, t)/\partial t]/[\partial \ln C(r, y, t)/\partial \ln y]$$

Under constant return to scale, we have that following:

$$[\partial \ln C(r, y, t)/\partial \ln y] = [\partial C(r, y, t)/\partial y]/[C(r, y, t)/y] = 1, \qquad (6)$$

implying that the rate of technical change is: $\partial \ln f(x, t)/\partial t = -[\partial \ln C(r, y, t)/\partial t]$, where a 1% upward shift in the production function is equal to a 1% decrease in the cost of production.

The rate of technical change can also be measured from the profit function, by estimating the profit function:

$$\pi(p, r, t), \text{ where } \pi(p, r, t) = \text{Max}_x\, [pf(x, t) - r'x] \qquad (7)$$

Using the envelop theorem, note that $\partial\pi(p, r, t)/\partial t = [p\ \partial f(x, t)/\partial t]$. It follows that the rate of technical change can be measured from the profit function as follows:

$$\partial \ln f(x, t)/\partial t = [\partial f(x, t)/\partial t]/y = [\partial \pi(p, r, t)/\partial t]/[p\, y] \qquad (8)$$

$$= [\partial \ln \pi(p, r, t)/\partial t]/[p\, y/\pi(p, r, t)] \text{ for } \pi(p, r, t) > 0$$

Total factor productivity indexes (*TFP* indexes) can also be derived.

Let t denotes a time t. Total differentiation of equation (3) with respect to x and t gives

$$[d \ln y] = \Sigma_i\, [\partial \ln f\,(x, t)/\partial x_i]\, d\, x_i + [\partial \ln f\,(x, t)/\partial t]\, dt \qquad (9)$$

It follows that the rate of technical change can be written as:

$$\partial \ln f\,(x, t)/\partial t = [d \ln y]/[dt] - \Sigma_i\, \{[\partial \ln f\,(x, t)/\partial x_i]\, [d\, x_i]/[dt]\}, \qquad (10)$$

The rate of technical change is the rate of output change that cannot be explained by the change in inputs between two periods. This implicitly treats technical change as a residual measure.

Denote by r_i the input price for the i-th input. Under cost minimization, note that $\partial \ln f\,(x, t)/\partial x_i = [\partial f\,(x, t)/\partial x_i]/y = r_i/[y\ \partial C(r, y)/\partial y]$, where we used the first order condition for cost minimization: $\partial f\,(x, t)/\partial x_i = r_i/[\partial C(r, y)/\partial y]$, $i = 1, 2, ..., n$.

It follows that, under cost minimization, equation (5) becomes:

$$\partial \ln f(x, t)/\partial t = [d \ln y]/[dt] - \Sigma_i \{[r_i/(y\, \partial C(r, y)/\partial y)]\, [dx_i]/[dt]\}, \quad (11)$$

$$= [d \ln y]/[dt] - \Sigma_i \{[r_i\, x_i/C(r, y)]/[\partial \ln C(r, t)/\partial \ln y]\, [d \ln x_i]/[dt]\},$$

where $[\partial \ln C(r, t)/\partial \ln y] = [\partial C(r, t)/\partial y]/[C(r, t)/y]$ and $[d \ln x_i] = [d\, x_i]/x_i$. But, under constant return to scale, $[\partial \ln C(r, t)/\partial \ln y] = [\partial C(r, t)/\partial y]/[C(r, t)/y] = 1$.

Thus, under constant return to scale, the equation takes the form:

$$\partial \ln f(x, t)/\partial t = [d \ln y]/[dt] - \Sigma_i \{w_i\, [d \ln x_i]/[dt]\}, \quad (12)$$

where $w_i = [r_i\, x_i/C(r, y)]$ denotes the i-th cost share, $i = 1, 2, ..., n$

Now consider a change from $t = 0$ to $t = 1$. Denote by x_i^t and y^t the observed value taken respectively by x_i and y at time t, $t = 0, 1$. Then, we have the following discrete approximations:

$$[d \ln y]/[d\, t] = \ln y^1 - \ln y^0 = \ln (y^1/y^0),$$

$$[d \ln x_i]/[d\, t] = \ln x_i^1 - \ln x_i^0 = \ln (x_i^1/x_i^0),\ i = 1, 2, ..., \mathrm{n},$$

$$w_i = \tfrac{1}{2}[w_i^0 + w_i^1],$$

where $w_i^{\mathrm{t}} = [r_i^t\, x_i^t]/[\Sigma_i\, r_i^t\, x_i^t]$ is the i-th input cost share at time t, $i = 1, 2, ..., \mathrm{n}$, $t = 0, 1$.

Using these approximations, we obtain the following:

$$\partial \ln f(x, t)/\partial t = \ln[y^1/y^0] - \Sigma_i \{\tfrac{1}{2}[w_i^0 + w_i^1]\, [\ln (x_i^1/x_i^0)]\} \quad (13)$$

The equation provides an empirically tractable measure of the rate of technical change from $t = 0$ to $t = 1$. Note that $I_O \equiv [y^1/y^0]$ can be interpreted as an output quantity index for the observation at $t = 1$, using $t = 0$ as a base. Also, note that $I_I \equiv \exp[\Sigma_i \{\tfrac{1}{2}[w_i^0 + w_i^1]\, [\ln (x_i^1/x_i^0)]\}]$ is the Theil-Tornquist index of input quantity for the observations at $t = 1$, using $t = 0$ as a base. The index I_I provides a measure of all the inputs used in the production process. This index is used in the empirical work.

It can be shown to be a superlative index. An index is said to be superlative if it is an "exact" index associated a flexible production function, for example, a production function that does not impose a priori restrictions on the Allen elasticities of substitution. It is also an exact index associated with the translog (flexible) production function, a functional form often used in econometric work.

The rate of technical change can thus be written as:

$$\partial \ln f(x, t)/\partial t = \ln [I_O] - \ln [I_I] = \ln [I_O/I_I] \tag{14}$$

Using $t = 0$ as a base, define a total factor productivity (TFP) index at $t = 1$ as follows:

$$TFP = I_O/I_I. \tag{15}$$

where I_O is an output quantity index and I_I is an input quantity index.

The rate of technical change is simply the logarithm of the TFP index (or equivalently that the TFP index is the exponential of the rate of technical change).

Since technical progress (regress) is defined by a positive (negative) rate of technical change, it follows that technical progress (regress) between period $t = 0$ and $t = 1$ corresponds to a TFP index greater than one (less than one). And, assuming TFP > 1, then [(TFP - 1)×100] can be interpreted in two ways, either as the proportion of output or revenue, when evaluated at constant output prices that has been generated by technical change between $t = 0$ and $t = 1$.

It can be interpreted as the proportion of inputs (or cost, when evaluated at constant input prices) that has been saved due to technical change between the two periods.

A total factor productivity index can be measured as:

$$TFP = I_O/I_I = \exp\{\ln[y^1/y^0] - \Sigma_i \{½[w_i^0 + w_i^1] [\ln (x_i^1/x_i^0)]\}\} \tag{16}$$

As an alternative, consider using profit maximization. Let p denote the competitive market price for output y. Under profit maximization, note that $\partial \ln f(x, t)/\partial x_i = [\partial f(x, t)/\partial x_i]/y = r_i /[p\, y]$, where we used the first order condition for profit maximization: $\partial f(x, t)/\partial x_i = r_i/p$, $i = 1, 2, ..., n$. It follows that, under profit maximization gives us:

$$\partial \ln f(x, t)/\partial t = [d \ln y]/[dt] - \Sigma_i \{[r_i/(p\, y)] [dx_i]/[dt]\}, \tag{17}$$

$$= [d \ln y]/[dt] - \Sigma_i \{[r_i\, x_i/(p\, y)] [d \ln x_i]/[dt]\},$$

Then, the equation takes the form:

$$\partial \ln f(x, t)/\partial t = [d \ln y]/[dt] - \Sigma_i \{s_i [d \ln x_i]/[dt]\}, \tag{18}$$

where $s_i = [r_i x_i/(p y)]$, $i = 1, 2, ..., n$. The rate of technical change becomes:

$$\partial \ln f(x, t)/\partial t = \ln[y^1/y^0] - \Sigma_i \{½[s_i^0 + s_i^1] [\ln (x_i^1/x_i^0)]\}, \tag{19}$$

where $s_i^{\mathrm{t}} = [r_i^t x_i^t]/[p^t y^t]$, p^t being the price of y^t, $t = 0, 1$.

And the corresponding TFP index is:

$$TFP = \exp\{\ln[y^1/y^0] - \Sigma_i \{½[s_i^0 + s_i^1] [\ln (x_i^1/x_i^0)]\}\} \tag{20}$$

Finally, in the multi-output case where $y = (y_1, y_2, ..., y_m)'$ is a $(m\times 1)$ output vector with corresponding prices $p = (p_1, p_2, ..., p_m)'$, the index under constant return to scale is:

$$I_O = \Sigma_i \{½[S_i^0 + S_i^1] [\ln (y_i^1/y_i^0)]\}, \text{ where}$$

$S_i^t = [p_i^t y_i^t]/[\Sigma_i p_i^t y_i^t]$ is the i-th revenue share at time t, $i = 1, 2, ..., m$, $t = 1, 2$.

4. Empirical Methodology and Results

The basic methodology employed in this study consists of estimating the manufacturing industry production functions with growth accounting and index theory principles for Mexico. The empirical approach explicitly measures the change in the structure and productivity of Mexican regions between 1985-1998, incorporating demand and supply forces, and including the contribution of factors like capital, which may affect productivity performance. The empirical analysis uses disaggregated data that includes measures of output, material inputs as intermediate goods (inclusive of energy) and labor used in the Mexican manufacturing sector. Capital stock was constructed using the perpetual inventory method from gross fixed capital formation and a 10% depreciation rate. Manufacturing comprises processing industry carried out by national establishments, processing by others, artisan crafts, and the offshore processing export industry. The data used in the estimation consists of the output and factors of production such as labor, capital and intermediate inputs for the period 1985 to 1998 in Mexican pesos taken from the industrial census and annual industrial survey of 1985, 1993 and 1998 published by INEGI and from the aggregate economic indicators and price deflator published by the Bank of Mexico. In the case of manufacturing, the main source is INEGI's Monthly Industrial Survey, where 205 types of activity are surveyed. The publication known as "Encuesta Industrial Mensual" also shows data on total remuneration and employed persons, broken down into workers and employees. This information is shown for 205 classes of manufacturing activities and includes hours worked. Each variable is aggregated for each manufacturing state in order to compare the rates of growth on output and factors of production as well as total factor productivity. The empirical analysis estimates the determinants of productivity growth by region, including the contribution of the factors and the term for productivity between 1985 and 1998. The data set if constructed at the state level, and aggregated at the regional level for the entire Mexican economy. The aggregate TFP estimate was revised significantly and in principle leads to a new set of estimates and results. With the use of the Tornqvist-Theil index we can adequately represent the preferences of producers and consumers as maximizing benefits and utility. The Tornqvist-Theil index is an exact index associated with the translog (flexible) homogeneous production function, a functional form often used in econometric work. This kind of production technology is used because it is now easier to empirically evaluate the expanded TFP model, by relying with a flexible functional form, which allows generality in terms of interactions among arguments of the function, such as substitution among inputs. Using these industry parameter estimates, we deduce the corresponding estimates for the state and aggregate regional economy.

From roughly 1950 to the 1970s, Mexico enjoyed a period of high economic growth with over 6 percent annual gross domestic product increases. After that, the 1980's became the "lost decade" and since then, Mexico's economy has never truly recovered its dynamic economic growth. It has been acknowledged by various authors that the recent regional change in Mexico, since the 1980's can be described as one where economic activity increases in northern states and decreases in the largest cities. In particular, the states of Distrito Federal, Jalisco, Mexico State, and Nuevo Leon are classified as the Largest Cities Region. These states are characterized by manufacturing activity that is consolidated under the import substitution industrialization and that features the highest levels of output per worker in the national manufacture. They also concentrated the economic growth rates since 1950 and contain the three largest industrialized cities in the country, Ciudad de Mexico, Guadalajara and Monterrey. The Northern Region includes the states of Baja California, Coahuila, Chihuahua, Sonora, and Tamaulipas. Manufacturing in this region is promoted by the Export Maquiladora Program since the 1960's and has been especially encouraged under the trade liberalization strategy of the 1980's and 1990's. Tax subsidies, transport cost advantage and agglomeration economies with the American southern states are the growth base for this region. A third and fourth region identify the performance of two regions of accelerated industrialization outside the Largest Cities and Northern regions. They are states that have steadily increasing their participation in the national manufactures since the 1960's. This newly industrialized periphery includes the Central Region, the states of Hidalgo, Morelos, Puebla, Queretaro and Tlaxcala; and the West-Central Region with the states of Aguascalientes, Guanajuato, Michoacan and San Luis Potosi. Then rest of the country includes the states of Baja California Sur, Colima, Chiapas, Durango, Guerrero, Nayarit, Oaxaca, Quintana Roo, Sinaloa, Tabasco, Veracruz, Yucatan and Zacatecas.

The reallocation of economic activity in the Mexican geography by state has been explained as result of the interaction of internal economies of scale, agglomeration economies, transport costs, and a moving of the central market from the largest cities to the northern states due to economic and trade liberalization policies. The implication of the analyses is understood by a change in economic strategy, from one based on import substitution to one based on trade liberalization. Under import substitution the central market was the internal market, which is where the largest population and cities in the country were located. During the industrialization process there was created a feedback between population and industrial location that resulted in concentration of the industry in the largest cities. This situation, which is widely documented in the literature on economic development, is explained in terms of internal economies of scale or firms producing for the internal market and taking advantage of minimization of transport cost and agglomeration economies. The regional location pattern under trade liberalization is discussed in Livas and Krugman (1992). They suggest a moving of the firms from the old central market, the largest cities, to the new central market, the border with the United States. Border firm clustering enables economies of scale as firms produce for both countries from one location. In the northern cities, firms minimize transport cost and after a while, they will create agglomeration economies which will encourage even more the attraction of economic activity towards the northern region.

By observing the estimates of manufacturing TFP for each region, regional variations are present in all regions. TFP growth from the period 1985-1998 is around 2.14% for the largest states and 1.73% for the rest of the country. A positive rate of TFP growth is observed for the period from 1970-93 for the biggest states and the rest of the states. The rest of regions show a mix performance, for instance, the west-central region has a positive 5.8% growth from 1985-1998 and a positive performance was shown by the rest of the country region, with a TFP growth rate of 1.7%. All these changes in productivity performance confirm in general, our previous conclusions on regional economic performance. There exists a positive 2.83% TFP growth in Mexico from 1985 to 1993. A significant increase, compared to the -0.8% TFP growth during the period that goes from 1973 to 1984 in Mexico. The results also show a positive 4.66% growth performance in the Northern region of the country which include the border states with the United States.

The establishment of NAFTA and the deepening of the economic globalization trend during the eighties and nineties have encouraged the shift of manufacturing production to the northern border region of Mexico. The process of manufacturing re-location undertaken during the period may be one of the causes of the positive TFP growth in the Northern region. Another explanation is the shift of manufacturing productive activities by foreign firms, which need to set up their activities where labor costs are low and locate close to the final markets for their products. A process of industrialization and urbanization has been experienced in the main cities of the northern border region. As an increasing number of manufacturing firms have established in that region, agglomeration economies have developed reinforcing the interaction of increasing returns to scale and transport costs.

The most important results are the differences in TFP manufacturing growth for the whole country using different techniques and comparing them to similar studies. The study estimates a 2.8% average annual TFP growth rate between 1985 and 1998, while De Leon (1995) found an annual average TFP growth rate of – 1.3% between 1970 and 1993. In 2013, INEGI released the results of the KLEMS Project for the Mexican economy which represents the most complete information generating effort on the subject which has so far been performed in Latin America. Following INEGI (2013), the effort was sponsored by the OECD and CEPAL and seeks to integrate a statistical and analytical platform based on the North American Industrial Classification Code 2007 (NAICS2007) that allows regional and international comparisons of the contributions of capital (K), labor (L), energy (E), raw materials (M), and services (S), and Total Factor Productivity (TFP) to output growth in the Mexican economy. The KLEMS Project for Mexico considered a vast processing of micro data from different sources of information which inegi processed the data under OECD standards to obtain the estimates of output, inputs, and TFP. The study provides growth accounting decompositions for 17 industrial branches and 67 sub-branches from three sectors (primary, secondary and tertiary) at an annual frequency for the period 1991-2011. INEGI (2016) found an annual average TFP growth rate of – 0.33% between 1991-2014 for the manufacturing sector. The findings raise a debate of Mexican productivity over time. One of them is that different measures of output and productivity, leads to different conclusions about productivity at the regional and national level in Mexico. The contribution of TFP to GDP growth has often been negative in Mexico. Based on INEGI's TFP data set, the analysis shows that, despite the negative contribution of TFP to output growth for the period in consideration, a positive association between the two variables is present.

The gap between developing regions and developed regions in Mexico has increased, in terms of regional GDP and manufacturing productivity. The manufacturing TFP growth rate of the Northern States of Mexico and West Central Region were more than twice the rate of growth of the rest of the country. High income regions are growing more rapidly in terms of productivity, and we observe a different growth rates between Baja California and Mexico City. Even though the economy in middle income regions are growing faster than the high income regions, we still find that the gap between the North, Central and the South of Mexico was growing larger and larger.

5. Conclusions

In the last three decades, many studies have analyzed the relative contribution of factor inputs and technical progress to economic growth. Since the seminal work of Solow (1957), total factor productivity (TFP), defined as the efficiency with which firms turn inputs into outputs, has been considered as the major factor in generating growth.

Measuring productivity is becoming important to economists and policy makers in Latin America. The analysis of economic growth begins with the construction of a set of growth accounts that decomposes the growth in output per worker into the contributions from the accumulation of physical and human capital and a residual measure of the change in total factor productivity (TFP). During the period of 1984 to 1994, Mexico had a -1.8% growth of TFP, while Chile had a 3.7% growth, Argentina had a 1% growth, Brazil a negative -0.2% growth in TFP, while the whole Latin American Region had a negative -0.4% growth in TFP.

According to recent economic growth estimates, the best decades in terms of economic growth in Mexico have been the 1950's, with an estimated annual average growth of 6.3%, the 1960's with an average annual growth of 6.63%, and the seventies with an average growth annual 6.43%. The 1980's is considered a lost decade in Mexico due to economic crisis caused by foreign debt and oil, with an average annual economic growth of 2.33% and negative -1.5% TFP growth estimate. An increasing acceleration of total factor productivity (TFP) growth in Mexico's manufacturing followed the liberalization process started in 1985 and enhanced with the passage of NAFTA. This development contributed substantially to the absolute and relative rise of the domestic economy's aggregate TFP residual, which is observed in the growth accounts by source of economic growth. TFP manufacturing growth was estimated at an annual average rate of 2.83% between 1985 and 1998, which is higher than the country annual TFP growth rate estimated by Santaella (1998) between 1980 and 1990 of -0.81% and 0.23% between 1990 and 1994.

Total factor growth contributes to economic growth and productivity at the manufacturing industry and national economy levels. However, the magnitude is much smaller than comparable estimates reported in the literature. An increase in the factors of production have an initial productivity effect by reducing total cost for a given level of output for all industries and at the aggregate economy level. This productivity effect induces output expansion in all industries, which in turn increases costs by requiring increases in input demands. When output level is allowed to vary, the productivity gains offset the cost increases required by the output expansion. An important result is the negative average contribution of TFP to output growth in Mexico with -0.39 percent for the period 1991-2011. For the case of Mexico, output growth, which averaged 3.58 percent, came entirely from the growth of its inputs. TFP growth in Mexico's largest cities and in the Northern Border States point out that the main contributor to productivity growth both at the industry and aggregate levels is exogenous demand represented by the growth in labor (with the effect of aggregate income and population growth).

A few decades ago, the Mexican economy was propelled by input driven growth. Labor was the main source of economic growth in the 1960's. We have now come to an innovation driven phase of economic development where labor and capital resources can no longer be the main sources to increase output in the manufacturing sector. The reason is that there is a limit to which capital investments can continue to grow in manufacturing before diminishing returns set in the Mexican Economy. Making the best use of our labor and capital resources, and a public policy that puts in place systems and programs that will encourage competition and innovation and achieve greater output per unit input will increase Mexico's economic and TFP growth in coming years.

References

Adams, J.D. (1990). "Fundamental Stocks of Knowledge and Productivity Growth." *Journal of Political Economy*, 98(4): 673-702.

Banco de México. (1998). "Indicadores Agregados de la Economía Mexicana". Banco de México, Informes Económicos, Various years.

Coelli, T., Rao, P. and Battese, G. (1998). *An Introduction to Efficiency and Productivity Analysis*. Norwell, Massachusetts: Kluwer Academic Publishers.

De León Arias, Adrián. (1995). *Recent Regional Change and Productivity in Mexico*. Universidad de Guadalajara, México.

De León, A. & Parra, E. (2011). "Crecimiento Económico en las Manufacturas Mexicanas: Un Análisis de Contabilidad del Crecimiento en las Entidades Federativas, 1988-2003". *Economía, Sociedad y Territorio*, 11(37), 575-607.

Hanson, G. H. (2010). "Why Isn't Mexico Rich?" *Journal of Economic Literature*, 48(4), 987- 1004.

INEGI. "Indicadores del Sector Manufacturero" (Manufacturing Sector Indicators), and "Encuesta Industrial Mensual" (Monthly Industrial Survey). Various years.

INEGI. Sistema de Cuentas Nacionales de México. Productividad Total de los Factores. Various years.

INEGI (2013). Sistema de Cuentas Nacionales de México. Productividad Total de los Factores 1990-2011. México, D.F.: Instituto Nacional de Estadística y Geografía.

INEGI. Anuario de Estadísticas Estatales y Censos Industriales. Various years.

INEGI. (2000). Anuario de Estadísticas Estatales por Entidad Federativa.

Krugman, Paul. (1994). "The Myth of Asia's Miracle". *Foreign Affairs*, 73, pp. 62-78.

Krugman, Paul. (1995). *Development, Geography and Economic Theory*. Cambridge: MIT Press.

Livas Elizondo, Raul and Paul R. Krugman. (1994). "Trade Policy and the Third World Metropolis". National Bureau of Economic Research. *Working Paper #* 4238, Cambridge, MA.

Salgado, H. & Bernal, L. (2007). "Productividad Multifactorial y sus Determinantes: Un Análisis Empírico para el Sector Manufacturero Mexicano". Bank of Mexico, *Working Paper* No. 2007-09.

Santaella, Julio. (1998). "Economic Growth in Mexico". Regional Operations Department, Country Division, IADB.

Solow, R.M. (1957). "Technological Change and the Aggregate Production Function". *Review of Economics and Statistics* 39, pp: 312-320.

Theil, H. (1967). *Economic and Information Theory*. North-Holland. Amsterdam.

Tornqvist, L. (1936). "The Bank of Finland's Consumption Price Index". *Bank of Finland Monthly Bulletin*, 16 (10), pp: 27-32.

Table 1
Regional Intermediate Factors of Production (IFP), Capital (K), Labor (L) and Total Factor Productivity (TFP) Growth Rates in Manufacturing between 1985 and 1998. (Percentage Growth).

Region of the Country	*IFP*	*K*	*L*	*TFP*
Central Region	7.26	1.71	2.65	1.11
Largest States	3.30	-1.92	0.50	2.14
Northern Region	5.57	-2.88	4.79	4.66
Rest of Country Region	6.00	-6.38	-1.36	1.73
West Central Region	7.34	-2.81	3.42	5.81
Mexico Country *	4.97	-2.94	1.82	2.83

* Note: Average percentage growth in manufacturing.

Table 2
Latin America Total Factor Productivity Growth Rates between 1960-1994 (percentage growth).

	1960-1973		*1973-1984*		*1984-1994*	
	GDP per Worker	*TFP **	*GDP per Worker*	*TFP **	*GDP per Worker*	*TFP **
Latin America	3.4	1.8	0.4	-1.1	0.1	-0.4
Argentina	2.6	0.2	0.4	-1.0	1.1	1.0
Bolivia	3.5	2.1	-0.6	-1.5	-0.1	0.8
Brazil	4.4	2.9	1.0	-0.8	0.5	-0.2
Chile	1.6	0.7	-0.6	-0.7	4.7	3.7
Colombia	2.9	1.9	1.2	0.0	1.8	1.0
Mexico	3.8	1.6	0.7	-0.8	-1.1	-1.8
Venezuela	1.2	0.9	-3.1	-4.3	-0.9	-0.4

*Note: Percentage growth of TFP, using country aggregate estimates.

Table 3
TFP Growth Accounting for Mexico (1991-2011).
Absolute Contribution of Inputs and TFP to Output Growth (Percentage Annual Average).

	Output	*Capital*	*Labor*	*Energy*	*Materials*	*Services*	*Contribution of Inputs*	
Period	*Y*	*K*	*L*	*E*	*M*	*S*	*K+L+E+M+S*	*TFP*
1991-1995	2.09	1.28	0.47	0.06	0.83	0.38	3.03	-0.93
1996-2000	7.1	1.47	0.72	0.2	2.54	1.05	5.99	1.11
2001-2005	2.39	1.61	0.29	0.08	0.55	0.61	3.15	-0.76
2006-2011	2.88	1.9	0.26	0.04	0.79	0.76	3.76	-0.87
1991-2011	3.58	1.58	0.43	0.09	1.16	0.7	3.98	-0.39

Source: Using data by INEGI (2013).

Table 4
Total Factor Productivity (TFP) and contribution to Economic Growth in Mexico. Using value of production, by sector of economic activity (Average annual percentage growth rate).

Sector	*Concept*	*1991-2014*
	Economy Total	**-0.33**
	Primary Sector	**0.22**
11	Agriculture, animal breeding, forestry , fishing and hunting.	0.22
	Secondary Sector	**-0.57**
21	Mining.	-1.92
22	Generation, transmission and distribution of electricity , water and gas transported by pipeline to the final consumer.	0.50
23	Construction.	-0.51
31-33	Manufacturing Industries.	-0.33
	Terciary Sector	**-0.08**
43	Commerce	-0.89
48-49	Transportation and storage.	-1.02
51	Mass media information.	2.97
52	Financial services and insurance.	0.31
53- 55	Real estate, rental furniture, intangible assets and Corporate Services.	0.52
54	Professional, scientific and technical services.	-4.63
56	Support services to business, waste management and remediation services.	-1.24
61	Educational services.	-0.77
62	Health and welfare.	-0.43
71	Cultural and sporting services, recreation, and other recreational services.	-1.46
72	Temporary accommodation services, food preparation and drinks.	-0.47
81	Other services except government activities.	-0.04
93	Legislative, governmental, law enforcement and international organizations.	-0.99

Source: Data by INEGI (2016)