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Productivity in Latin America. An analysis using a Cobb-Douglas function

La productividad en América Latina. Un análisis a través de una función Cobb-Douglas

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Resumen: en América Latina el limitado crecimiento de la actividad económica se ha caracterizado por su fuerte correlación con la baja productividad, es por ello que se analiza el comportamiento de la Productividad Total de los Factores (PTF) en esta región. El objetivo de esta investigación es examinar el papel del trabajo (L), el capital (K) y el cambio tecnológico (A) en la evolución de la PTF en América Latina durante el periodo 1990-2019. Se instrumenta un modelo de datos panel mediante el estimador de "Grupo de Medias Agrupadas" (PMG), para catorce economías durante 29 años. En los resultados se evidencia la existencia de dependencia transversal y raíz unitaria de orden I(1). Se presenta una relación de largo plazo entre las variables y se encuentra que el trabajo (L), el capital (K) y el cambio tecnológico (A) inciden positivamente en la PTF. Se encontró que, en el corto plazo, el capital (K) tiene un impacto mayor que el cambio tecnológico (A) en la PTF; mientras que, en el largo plazo es el cambio tecnológico (A) el que más influye. El modelo muestra una velocidad de ajuste del 18 %, lo que implica un tiempo de corrección estimado de 5.5 años. En conclusión, en el trabajo se da cuenta de la importancia de fortalecer la innovación y el desarrollo tecnológico en la región, para mejorar la productividad y el crecimiento económico.

Palabras clave: Productividad Total de los Factores (PTF), crecimiento económico, datos panel, función de producción Cobb-Douglas, Grupo de Medias Agrupadas (PMG).

Abstract: in Latin America, the limited growth of economic activity has been characterized by its strong correlation with low productivity, which is why the behavior of Total Factor Productivity (TFP) in this region is analyzed. The objective of this research is to examine the role of labor (L), capital (K), and technological change (A) in the evolution of Total Factor Productivity (TFP) in Latin America during the period 1990-2019. A panel data model is implemented using the "Pooled Mean Group" (PMG) estimator for fourteen economies over a period of 29 years. The results show the existence of cross-sectional dependence and a unit root of order I(1). A long-term relationship between the variables is presented, and it is found that labor (L), capital (K), and technological change (A) positively impact TFP. It was found that, in the short term, capital (K) has a greater impact than technological change (A) on TFP; whereas, in the long term, it is technological change (A) that has the most influence. The model shows an adjustment speed of 18%, which implies an estimated correction time of 5.5 years. In conclusion, the work highlights the importance of strengthening innovation and technological development in the region to improve productivity and economic growth.

Keywords: Total Factor Productivity (TFP), economic growth, panel data, Cobb-Douglas, Pooled Mean Group (PMG).

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Introduction

Latin American context

Slow economic growth is a problem that has characterized Latin America, according to data from the World Bank (2023), since the 1990s the countries that make up this region have had a percentage growth of their Gross Domestic Product (GDP) of 2.5%, below the world average, which for these years was 2.9% per year. This situation can be due to several structural factors; however, it is also associated with the efficiency of economies and their productivity (ECLAC, 2016).

The growth of economic activity is correlated with productivity. In the Latin American context this situation has revealed a delay, which limits the development of these countries. The analysis of Total Factors Productivity (TFP) represents a fundamental element for middle-income economies, and since it explains a part of the lag that they face, several authors identify that it is through the improvement in productive efficiency where they can close the gap in income distribution (Kim and Park, 2017; Yalçınkaya *et al*., 2017).

In Latin America there is a great limitation associated with the informality of the economy, hence workers do not have access to social security directly, affecting their productivity, and companies are outside the fulfillment of their fiscal obligations which limits access to financing (Aravena and Fuentes, 2013; Ros, 2008). This factor that has characterized the region affects the performance of the factors of production, and therefore the TFP.

Additionally, it is considered that technological progress in the region, an element that should be fundamental to achieve economic growth, has not played a key role in the development of TFP; this fact is evidenced in the light of a limited number and below the global average of patent applications (World Bank, 2023c), and low investment in R&D (World Bank, 2023b), demonstrating the technical inefficiency of the economies involved in this article that limit the development of their TFP, which negatively affects their economic growth.

Fundamentals

In this work, TFP has an important role since it is a macroeconomic indicator that is framed in the accounting of growth, which identifies the performance of factors of production labor (L), capital (K) and technological change (A) as determinants of production in the sense of Cobb-Douglas (1928), so, that its analysis is very useful for the application of economic policy measures (Barro and Sala-i-Martin, 2012).

The objective of this work is to analyze the behavior of production factors in the development of TFP for Latin American economies during the period 1990-2019. The first contribution of this research is related to the use of the Group estimator of Grouped Means proposed by Pesaran *et al.* (1999), which allows estimating the long-term coefficients and the error correction coefficients, while generating the specific short-term coefficients through a maximum likelihood estimate. The second contribution of the research is that it tests the hypothesis that labor, capital, as well as technological change have been the determinants of TFP of Latin American economies during the period 1990-2019, this from the Cobb Douglas production function.[1]

This work is divided into six sections. The first presents the introduction. The second corresponds to the review of the literature, specifically the production function and growth models. The third shows the empirical evidence of the variables. The fourth develops the methodology and databases. The fifth section presents and analyzes the results Finally, the sixth section presents the conclusions derived from this study.

1 Technique used to measure the rate of productivity growth of an economy by subtracting the growth that is due to the accumulation of growth factors (Weil, 2006).

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Revisión de literatura

Desde sus inicios, la ciencia económica ha tenido como objetivo analizar el crecimiento de los países, así como sus diferencias, desde la perspectiva neoclásica es posible abordar los elementos que son determinantes en la producción de un país, a partir del desempeño de los factores de la producción, es decir, del trabajo y del capital, así como del cambio o avance tecnológico, es por ello que en este apartado se realiza un análisis de las teorías que han explicado estas disparidades, tomando como base la función de producción Cobb-Douglas (1928).

Función de producción Cobb-Douglas

Literature review

Since its inception, economic science has aimed to analyze the growth of countries, as well as their differences. From the neoclassical perspective, it is possible to address the elements that are essential in the production of a country, from the performance of the factors of production, i.e., labor and capital, as well as change or technological advancement. For this reason, in this section an analysis of the theories that have explained these differences is made, taking as a basis the Cobb-Douglas production function (1928).

Cobb-Douglas production function

The background of the production function is found, on the one hand, in Clark's (1899) and Wicksteed's (1894) theory, which propose that it is possible to determine the size of production from the combination of labor and capital factors. On the other hand, there is the influence of Wicksell (2001), who highlights the importance of analyzing economic cycles, identifying that they are consolidated from an external force, which he called technical progress. Later, Cobb and Douglas (1928), make a contribution grounded in the empirical evidence of the U.S. economy.

In their work, Cobb and Douglas (1928) present from the information of the manufacturing industry of the United States the function of neoclassical production, expressed in the following terms:[2]

$$Y = AK^{\alpha}L^{\beta}$$

where:

Y= Production.

A= Technological progress or TFP.

K= Capital stock or capital factor (set of goods or assets used to produce).

L= Number of workers or labor factor.

α = Parameter indicating the productive capacity of the capital factor.

β= Parameter indicating the productive capacity of the labor factor.

The parameters indicate the rate of change that labor or capital exerts in the production of manufacturing industry, so that the first derivative indicates the proportion of the variation that factors have in the growth of production, i.e., the marginal productivity of capital (α) and labor (β) is presented.

Cobb and Douglas (1928), consider in their article that there are constant returns, i.e., the sum of the parameters is equal to 1, however, there are other cases such as decreasing returns, where adding the parameters gives a result lower than the unit, while if it were greater than 1 would be classified as increasing returns to scale. Cobb and Douglas (1928) mention that production, labor and capital are related, so that, if the latter two are multiplied by a factor, production increases in that amount, that is in m times, i.e., production is a first-degree homogeneous labor and capital function.

The result of Cobb and Douglas (1928) is in congruence with the production function of Clark (1899) and Wicksteed (1894). The authors consider that it is possible to quantify from the method of Ordinary Least Squares (MCO); with this contribution to economic theory, they present an innovative proposal in the studies of economic growth.

2 In the original document, the coefficients with nomenclature P', L and C are considered.

Growth Models

Within the framework of the neoclassical approach, there are various perspectives that explain economic growth. On the one hand, there are those theories that identify growth in an exogenous way, i.e., the variables that explain economic growth are outside the model, in addition, the idea that once the stationary state has been found, the capital-product relationship does not vary, thus obtaining a fixed relationship. This would imply that in the long term, productive activity is limited by exogenous factors on both the supply and demand (Perrotini *et al*., 2019). On the other hand, there are theories that determine that the growth rate is not in a steady state, therefore, human capital should be encouraged, as well as its capabilities and abilities, which would lead to an improvement in the technological factor (Jiménez, 2011).

During the 1950s to the 1990s, exogenous growth models that identified the so-called steady state predominated, where factors of production, labor, and capital did not cause an increase in output growth, i.e., they caused diminishing returns. Therefore, an exogenous force could cause this situation, i.e., this phenomenon can be observed from the technological advances of the countries, and the main exponent of this current is Solow (1956). It recognizes that, in the long term, it will be the increase in the saving rate and technological progress, i.e., the variations in constant A, that will cause economic growth. The optimal growth model developed from the works of Ramsey (1928) and later retaken by Koopmans and Cass (1965), show from the microeconomic perspective the decision of households and companies between savings and consumption, and how this situation will affect intertemporal well-being and economic growth return to the idea of technological progress exogenously.

The growth model of Mankiw *et al*. (1993), takes up the ideas of Solow's residue identifying that said author would be right to consider the factors of production, however, a greater weight should be given to the factor work since it will be the workforce which, through their skills and knowledge, generate a change in economic growth. In short, exogenous growth models identify that, in the long term, the only way to generate an increase in output will be if technological improvements are implemented.

During the 1990s, economic studies showed a strong rejection of the so-called stationary state, thus endogenizing the variables th*et al*low to achieve a growth of production. According to various authors, the role of workers will be decisive and does not come from foreign or external sources, because it is this factor either through the acquisition of knowledge and skills, or by the positive externalities generated by R&D that increases their productivity and therefore economic growth in a sustained way (Romer, 1986; Baumol, 1986; Lucas, 1988). In addition, there are other works that identify the importance of public spending and investments in R&D, as well as stability in monetary and fiscal policies and the role of institutions as elements that promote economic growth (Barro, 1991; Rebelo, 1991; Howitt, 2004).

To sum up, endogenous models consider that, in order to achieve economic growth in a sustained way, it is necessary to encourage human capital, and this will be possible through investment in R&D, since it generates positive externalities, such as the increase in productivity in this factor. In other words, it will be possible to have increasing or constant returns to scale, together with the role of institutions and macroeconomic stability to achieve economic expansion of countries.

Empirical evidence

The literature review allows to identify some aspects of TFP in different contexts, in this sense, there are works that consider the role that TFP has had in economic growth (Hofman *et al*., 2017; Kim and Park, 2017; Villalobos *et al*., 2021; Yalçınkaya *et al*., 2017). Other studies focus on quantifying the contribution of production factors in TFP growth (Ayvar and Guitrón, 2013; Maudos *et al*., 1999; Nguyen, 2021; The Conference Board, 2023). In addition, there is empirical evidence that analyzes the impact on TFP of other variables such as macroeconomic imbalances, terms of trade, volatility in trade or importance in R&D (Dańska-Borsiak and Laskowska, 2012; Gutiérrez Villca, 2020; Méndez *et al*., 2013).

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In the studies that aim to study the influence of TFP on economic growth, it is possible to generalize the similarities that exist in the results to which various authors arrive that reveal the importance of TFP, even above the factors of labor and capital production in economic growth (Kim and Park, 2017; Yalçınkaya *et al*., 2017). Latin American studies show evidence in this regard, since they present negative contributions in TFP growth, this being a consequence and explanation for the low economic growth (Hofman *et al*., 2017; Méndez *et al*., 2013; Villalobos *et al*., 2021).

The works that analyze the contribution of factors production consider, on the one hand, that the labor or human capital factor influences TFP more significantly (Ayvar and Guitrón, 2013; Maudos *et al*., 1999), while for other studies it is the capital factor that has the greatest impact on TFP (Nguyen, 2021; The Conference Board, 2023), but these results should be considered for different economies in different contexts.

There are Latin American studies, not framed in the production function approach, that consider variables that explain the behavior of TFP. On the one hand, there are studies that directly relate TFP with technical efficiency, technological progress, terms of trade, Foreign Direct Investment, savings, average productivity per worker, schooling and life expectancy (Gutiérrez, 2020; Méndez *et al*., 2013; Ramírez and Aquino, 2005). On the other hand, Gutiérrez (2020) finds a negative relationship of TFP with macroeconomic imbalances, volatility in trade, informality, fertility rate, inequality and external crises. Finally, Ramírez and Aquino (2005), present an inverse relationship between inflation crises and TFP.

The revised papers emphasize the importance of the R&D variable, since it will be the efforts in technological progress that cause the increase in TFP, and thus generate higher economic growth (Dańska-Borsiak and Laskowska, 2012; Méndez *et al*., 2013; Nguyen, 2021).

More recent studies analyze the behavior of East Asian economies, through panel data methodologies, adding other elements in which they stand out: real investment, the accumulation of physical capital, the number of average hours of work, the development of human capital, as well as the internal rate of return as key factors in TFP growth (Lee and Viale, 2023). The work conducted by Rehman and Islam (2023), focuses on the BRICS economies and highlights the importance of financial infrastructure in both the short and long term, trade openness, FDI, human capital, innovation and institutional quality as factors that affect TFP.

In another study approach, the importance of green TFP (GTFP), as an efficiency measure aimed at environmental sustainability, is highlighted. On the one hand, traditional factors of production are considered, and on the other hand, impact is integrated into the environment, promoting more sustainable approaches. This type of work has greater application in the Chinese economy (Jiakui *et al*., 2023; H. Liu *et al*., 2023; Liu *et al*., 2023). Likewise, there are works that analyze the impact of digital technology (Pan *et al*., 2024), green finance (financial flows for sustainable projects) (Feng *et al*., 2024; Yue *et al*., 2024), as well as the development of the internet and mobile broadband for determining green TFP (Edquist, 2024; Wen and Deng, 2024).

Materials and methods

In this research, growth models are analyzed using panel data methodology. The benefits of this type of models compared to a typical cross-sectional model have been taken into account, or they would also be able to control individual heterogeneity and identify the effects that would have been undetectable in traditional time series data.

In this paper, the empirical specification of the panel data model is as follows:

$$InPTF_{it} = \theta_{0i} + \theta_1 lnK_{it} + \theta_2 InL_{it} + \theta_3 InA_{it} + u_{it} \quad (1)$$

Where the value represents the average of the variables in the long term, such that the logarithm of TFP is based on the logarithm of the capital factor (K); secondly, the logarithm of the labor factor is considered and finally the TFP is defined by technological change and is the error term.

As specified by Pesaran *et al*. (1999), it is possible to carry out a reparameterization in order to make a PMG estimate, leaving the equation in the following terms:

$$\Delta PTF_{it} = \phi_i \text{PTF}_{i.t-1} + K_{it}\beta_1 + L_{it}\beta_2 + A_{it}\beta_3 \sum_{J=1}^{p-1} \lambda_{ij}^{*} \Delta PTF_{i.t-j} + \sum_{J=0}^{q-1} \Delta \mathrm{K}_{i,-j} + \sum^{q-1} \Delta L_{i.-j}\, \delta_{ij}^{*} + \sum^{q-1} \Delta L_{i.-j}\, \delta_{ij}^{*} + \mu_i \iota + \varepsilon_{it} \quad (2)$$

where:

φi: = Error correction rate parameter of the adjustment term.

PTF_{it}= Vector of T x 1 of the observations of the dependent variable in Latin American economies.

K_{it}= T matrix of observations on the regressors of the capital independent variable that vary between groups in the time period.

L_{it}= T matrix of observations on the regressors of the independent variable work that vary between groups in the time period.

A_{it}= T×k matrix of observations on the regressors of the independent variable technological change that vary between groups in the time period.

ι = (1,…, 1) is a vector T x 1 of the PTFi,-j, K i-j, L i-j, A i-j are j lagging values of the period of PTFit, Kit, Lit and Ait.

λ_{it} = Scalars.

δ= Vectors of coefficients k x 1.

ε_i= Error term.

Transverse dependence test

Pesaran (2004) proposes a statistic by eliminating the calculation method that had traditionally been considered, i.e., the spatial matrix was incomplete to specify if the data had dependence. This metric did not allow the capture of common factors (economic or sociopolitical) that are determinants and that generate dependence. The Pesaran CD test (2004), is a valid routine when N and T →∞ under any order.

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \hat{\rho} ij\right)} \sim N(0,1)1 \quad (3)$$

Decision-making to determine whether or not there is cross-sectional dependence assumes that the uit error term is independent and identically distributed (i.i.d.) over periods and among cross-sectional units (Pesaran, 2004).

CADF Unit Root Test

Variables that are observed over time require a series of tests that ensure that they are stationary "generally speaking, a series of time is stationary if its mean and variance do not vary systematically over time" (Gujarati and Porter, 2010).

There is a methodology thet allows identifying the unit root when there is dependence on the cross section (Im *et al*., 2003), thus relaxing the assumption of cross-sectional independence that the first-generation tests contested since "they were quite restrictive and unrealistic in macroeconomic applications" (Hurlin and Mignon, 2006, p. 3).

The stationarity test (Im *et al*., 2003) consists of increasing the standard regressions with the cross-section averages, starting from the lags and the first differences for each series, thus having simple averages increased transversely, which would result in a new statistic called CADF. The development of the model is specified from the standard Dickey-Fuller regressions with the average of the cross-section of the lagging levels and of the first differences.

A model for N cross-sections observed at T periods is considered:

$$Y_{it} = (1-\phi_i)\mu_i + \phi_i Y_{it-1}) + \varepsilon_{it} \quad (4)$$

The interest results in the values of testing the null hypothesis of unit roots for all i (Hi = 1), which can be expressed in the following equation:

$$\Delta Y_{it} = \alpha_i + \beta_i Y_{it-1} + \varepsilon_{it} \quad (5)$$

Where:

$\alpha_i = (1 - \varphi_i)\mu_i$

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$\beta i = -(1 - \varphi_i)$

$\Delta Y_{it} = Y_{it} - Y_{i,t-1})$

Co-integration

Panel data models have the possibility of establishing long-term relationships which can be verifiable through the cointegration test. Traditionally, the test required that short-term parameters be equal to long-term ones, which would show a failure to put a common factor constraint. The test proposed by Westerlund (2007), is designed under the null hypothesis of non-cointegration.

The cointegration model developed by Westerlund (2007), can be specified as follows.

It is considered the next data generation process

$$\begin{gathered} y_{it} = \phi_{1i} + \phi_{2i}t + z_{it} \\ x_{it} = x_{it-1} + v_{it} \end{gathered} \tag{6}$$

Where it is a deterministic scalar, the vector is a random walk and is the stochastic term. While t = 1,…,T and i = 1,…,N express the time series and cross-section units, respectively.

The cointegration test presented consists of four statisticians, two of them group the information about the error and are called panel statistics (Gt and Ga), while the others show the statistics (Pa and Pt) of the means in the groups, suggesting that at least some unit is cointegrated (Persyn and Westerlund, 2008).

Pooled Mean Estimator for Dynamic Panels (Pooled Mean Group)

Traditionally, estimators for panel data assumed that the coefficients and variances of errors did not differ between groups. Given the characteristics of individuals or economic units, it was difficult to assume that the variances of the error were equal in the short term. For this reason, Pesaran *et al*. (1999), propose a new way to make estimates for panels with large N and T through the estimator for means grouped in dynamic panels Pooled Mean Group (PMG), which conditions the coefficients in the long term to be identical.

According to Pesaran *et al*. (1999), in the long-term equilibrium relations are expected to exist, which would be expressed by homogeneous, or similar variables between the groups. This would seem visible when considering certain conditions that similarly influence the panel, such as budget constraints or common technologies.

An Autoregressive Distributed Lag Model (ARDL) is one that considers lags in the variables or what is the same, delays are introduced in the variables of the vectors contemplated (Cho *et al*., 2023).

These models aim to test the cointegration of variables. The proposal of Pesaran *et al*. (2001), is made from a limit test to find the relationships in the long term through an error correction mechanism, which allows to identify the adjustment dynamics of the variables in the short and long term. The panel is given by the equation:

$$y_{it} = \sum_{J=i}^{p} \lambda_{ij} y_{i,t-j} + \sum_{J=0}^{q} \delta'_{ij} x_{i,t-j} + \mu_i + \varepsilon_{it} \tag{7}$$

Where:

Yit = Group-dependent variable i.

xit: = Vector of explanatory variables (regressors) for group i.

μi: = Fixed effects (the coefficients of the lagging dependent variables).

λij = Scalars.

δij = vectors of coefficients kx1.

Databases and information sources

In this work, Total Factor Productivity is recovered from the Penn World Table version 10.0 database (University of Groningen, 2021), and obtained through the Törnqvist index considering the prices of the factors that are implicit in the prices of goods (Feenstra *et al*., 2015).

Total Factor Productivity is calculated using purchasing power parity rates for each country relative to the United States; and is expressed as follows:

$$\text{CTFPjk} = \frac{CGDPoj}{CGDPok} / \text{Qt (vj, vk, wj, wk)} \qquad (8)$$

Where:

CTFPjk = is the total factor productivity at current prices of each country j relative to k. For that purpose, the reference prices of the United States are used.

$\frac{CGDPoj}{CGDPok}$ = It is the change in GDP at current prices.

Qt (vj, vk, wj, wk) = is the Törnqvist index of the endowment of factors of production.

The work factor was obtained from the World Bank database (2023c) and is defined as those workers who have a type of paid employment, this implies that they have some contract (written or oral) that guarantees their salary.

In the capital factor, the capital services indicator was used, which was obtained from the Penn World Tabble version 10. 0 databases (University of Groningen, 2021). The indicator is obtained as follows: a) through initial inventories based on the perpetual inventory method; b) through the Gross Fixed Capital Formation deflator; c) the return on capital in the economy is included, considering the Internal Rate of Return (IRR) (Inklaar and Woltjer, 2019).

For the measurement of technological change, the indicator of the industrialization intensity degree is considered as a proxy variable that reflects the technological change of Latin American economies (United Nations Industrial Development Organization, 2013).

The industrialization intensity indicator (INDint) is obtained as follows:

$$\text{IND}_{\text{int}} = \frac{MHVAsh+MVash}{2} \qquad (9)$$

Where:

MHVash = is the share of the value added of medium and high-tech manufacturing in the value of total manufacturing.

MVash = is the share of manufacturing value added in total GDP (United Nations Industrial Development Organization, 2022).

Results and discussion

This section presents the results of cross-sectional dependence, stationarity of the series, long-term cointegration between the panels and the estimation process through the PMG methodology of Pesaran *et al*. (1999).

Cross-sectional dependence analysis

Through the Pesaran CD test (2004), the existence of cross-sectional dependence in the variables studied is verified. The results show that the probabilistic value, both in the dependent variable, and in the independent ones is 0.000. According to the specification and criteria referred to in the methodological development section, the null hypothesis proposes that there is transverse independence; this can be rejected, allowing to conclude that there is transverse dependence. Through the test we obtain the average of the pairwise correlation coefficients of the MCO residues of the individual regressions in the panel, and it can be used to prove the cross-section dependence of any fixed order p, as well as the case where an order of the a priori cross-section units is not assumed (see table 1).

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Table 1

Cross-section dependence test results

	lnPTF	*lnck*	*lnLw*	*lnA*
prom ρ	0.09	0.70	0.31	0.28
prom |ρ|	0.50	0.78	0.44	0.37
CD	5.00	35.94	16.91	14.40
p-value	0.00	0.00	0.00	0.00

Note. Own elaboration based on the estimates made in Stata 17.

CADF Unit Root Test

Considering that there is cross-sectional dependence on the variables studied, it is possible to use the 2nd generation unit root tests. With the stationarity methodology (Im *et al*., 2003), it is considered from the CADF statistic that the critical values consider that the null hypothesis of non-stationary series should be rejected. It is sought that the probabilistic values are less than 0.05, the summary of the test for each variable and in its first difference can be observed in table 2.

Table 2

Results of Pesaran unit root tests (2003)

lnPTF		*lnck*		*lnLw*		*lnA*	
Zt-bar	**p-value**	**Zt-bar**	**p-value**	**Zt-bar**	**p-value**	**Zt-bar**	**p-value**
2.81	1.00	5.07	1.00	-0.83	0.20	-1.20	0.11
ΔlnPTF		*Δlnck*		*ΔlnLw*		*ΔlnA*	
-9.91	0.00	-3.08	0.00	-13.9	0.00	-13.2	0.00

Note. Own elaboration based on the estimates made in Stata 17.

The variables fulfill their characteristic of being stationary in their first difference, so we can reject the null hypothesis of non-stationarity according to the test of Im *et al*. (2003), second generation, thus concluding that the variables have integration order one, I (1).

Co-integration analysis

If the Westernlund test (2007) occurs in this way, based on the cointegration of the panel, the probabilistic values of some of the four criteria would be below the levels of significance. In the test carried out for the selected Latin American economies, it is shown that two of the Gt and Pt criteria are 0.04 and 0.00 respectively, so it is possible to say that the panel is cointegrating (see table 3).

Table 3

Westerlund cointegration test results (2007)

Statistic	Value	Z-value	P-Value
Gt	-3.12	-1.81	0.04
Ga	-10.18	2.48	0.99
Pt	-11.72	-2.66	0.00
Pa	-13.23	-0.53	0.30

Note. Own elaboration based on the estimates made in Stata 17.

The Pooled Mean Group (PMG) estimator for TFP analysis

Through the estimator PMG proposed by Pesaran *et al*. (1999), which considers the maximum likelihood of long-term coefficients, it is possible to perform a grouping given the homogeneity conditions in the coefficients. As the author specifies, it is possible to determine through an error correction mechanism that the coefficients of slopes and variances of the error differ in the short term, and it is possible to present homogeneous estimators in the long term, having the results that are observed in table 4.

Table 4

Results of Pesaran's Pooled Mean Group model (1999)

Pooled Mean Group			
Variables	Coefficients	Prob Value.	Standard Error
Long term			
lnK (L1)	0.018	0.009	0.006
lnL (L1)	0.087	0.009	0.033
InA (L1)	0.073	0.013	0.029
Short term			
lnK (D1)	0.135	0.000	0.035
lnL (D1)	0.580	0.001	0.180
lnA (D1)	0.074	0.039	0.036
Error Correction (O)/	-0.182	0.010	0.070
Intercept	-0.046	0.000	0.012

Note. Own elaboration based on the estimates made in Stata 17.

The estimated ARDL model is of order (1, 1, 1) based on the methodology proposed by Pesaran *et al*. (1999). The first 1 assumes that there is a model that has a delay for the calculation of the long term, the second refers to the moving average, and the third one is considered as the differentiation of the variables in the model, which allow to present coefficients in the short term.

Based on the empirical evidence, it is possible to draw some conclusions regarding the variables used. At the top of the table in the long-term model are significant estimators—the probabilistic values are less than 0.05. The relationship between the variables is expected, i.e., the working hypothesis in this research is tested in which a direct relationship between TFP and independent variables is established —according to neoclassical economic theory—.

In the long term, with a change of 1% in the work variable, TFP increases by 0.0871% in the selected Latin American economies in the period 1990-2019. The interpretation of this behavior shows that jobs and firms that support workers with medical services, and various benefits have a positive impact on TFP. In this sense, informality and self-employment (which would be the workers that are not included in the selected work variable), are the sectors with the lowest productivity, i.e., the more informality and self-employment there is in Latin American countries, the lower the TFP.

A second element that is rescued in the long term is technological change. The empirical evidence reveals that, in the face of unit percentage

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changes of this variable, TFP increases by 0.073%, demonstrating the importance of having a high degree of industrial intensity in Latin America. This is consistent with the theory of economic growth proposed by Solow (1956), which specifies that, in the long term, technological progress will be decisive in achieving economic growth.

As far as the capital factor is concerned, this has a small elasticity, indicating that in the event of a change of 1 % in the variable, the TFP would increase by 0.018 %. This variable was the least representative in the long term, while labor is the most important for Latin American economies in the period 1990-2019.

Table 4 also has evidence for the short term. In this case, the estimators are significant with probabilistic values less than 0.05, and just as in the long term, these have positive relationships of labor, capital and technological change with respect to TFP.

The work factor presents a similar behavior in the short and long term, in the sense of being the variable that has a greater incidence in the TFP; however, there is a greater elasticity. In the face of unit changes in this variable, TFP increases by 0.580%, accounting for the importance of formal work in the economies studied in this research.

In this case—in the short term—the key factor is its importance in determining TFP growth, with a coefficient of 0.135. Hence, the accumulation of production factors in the short term, further define economic growth in correspondence with exogenous growth models.

Regarding technological change, in the short term we face unit percentage changes in this variable, in which the TFP increases by 0.74%. This coefficient is similar to the long-term, however, for the short term it would occupy the third position in order of importance.

Finally, the evidence for the error correction mechanism (O) shows the rate at which the model converges to equilibrium in the long term. It also meets the model specifications, i.e., it is negative, lower than unit and significant (Blackburne & Frank, 2007; Pesaran *et al*., 1999). The interpretation of (O) shows that in the face of shocks or alterations of the selected variables, the model is corrected by 0.182, i.e., by 18% annually. In this way, the adjustment speed of the model is reached in 5.5 years,[3] which would reflect the adjustment dynamics of the short to long term.

Conclusions

This paper reviews the factors that influence TFP growth from the Cobb-Douglas production function in fourteen Latin American economies—Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Jamaica, Mexico, Paraguay, Peru, Uruguay, and Venezuela, during the period 1990-2019.

The methodology used is the estimation for panel data of the "Group of Grouped Means" (PMG) to capture the behavior of the factors of production, labor and capital, as well as the technological change on TFP. In this process, the tests of cross-sectional dependence, unit root and cointegration are considered.

Tests were carried out prior to the estimation process of the panel data model, showing that there is cross-sectional dependence of the variables in the selected economies. The behavior of the series is stationary with integration degree of I(1) and the variables in the long term are cointegrated. In the estimation process, the proposal of Pesaran *et al*. (1999) PMG, which combines dynamic data panels and group mean estimators, is applied.

From the estimation results of the PMG model, evidence was found that in the short and long term, in which the variables work, capital and technological change have a direct relationship with TFP. In the coefficients of the work, it was found that in the long term before a change of 1% in this variable the TFP would increase by 0.0871%; while, in the short term the increase in the TFP would be of 0.580%.

In the long term, changes in the capital factor by 1 % cause TFP to increase by 0.018 %, while in the short term there is a greater increase of 0.135 %. As regards technological change, in the long

3. To calculate the rate at which the model converges to equilibrium, consider 1/O, resulting in the time at which variables are balanced over the long term (Asteriou & Hall, 2021).

term a change of 1 % results in an increase in TFP of 0.073 %; in the short term, the effects of this variable on TFP are similar to those in the long term (0.074 %).

In the long and short term, the order of importance of the effects of explanatory variables on TFP presents significant changes. The labor factor before the capital and technological change is the one that most influences the TFP, while the capital in the short term occupies the second place, and in the long term it has the third position. As for the technological change, in the short term it has the third order of importance and in the long term it is in the second position. Hence, the neoclassical economic theory approach of exogenous growth models proposed first by Solow (1956) is corroborated, which establish that in the long term, it will not be the accumulation of physical factors that leads to economic growth, but technological progress.

The hypothesis established in this article is confirmed according to which capital (K), labor (L), and technological change (A) were the determinants of TFP in the economies of Latin America during the period 1990-2019.

The future lines of research should: a) consider studies at the subregional level in Latin America in order to identify similar economic conditions between countries and thus, review the incidence of the independent variables of this research in the TFP of these geographical spaces; b) conduct the study at the sectoral level, to review comparatively the influence of factors of production and technological change in the TFP of Latin American economies; and, c) incorporate the environmental variables within the main guidelines of this work, given the importance that has been acquiring the green TFP (GTFP), as an indicator focused on environmental sustainability.

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