RESEARCH ARTICLE

Impact of economic growth on scientific production in Latin America and the Caribbean based on panel data analysis [version 1; peer review: 2 approved with reservations, 1 not approved]

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Abstract

Background: The great difference in scientific production among countries, especially in Latin America and the Caribbean, may be related to the economic growth of each nation, but countries with larger economies do not necessarily have higher scientific production. Political changes and unstable economies result in little sustainability of scientific production in the countries in these regions. The purpose of this study was to determine the impact of economic growth on scientific production, measured as the variation in the gross domestic product and the number of scientific publications, in Latin American and Caribbean countries.
Methods: The analyzed information was collected from the open data source of the World Bank for the years from 2000 to 2018. The analysis was performed using unbalanced data panel models that cross-sectionally considered the countries of Latin America and the Caribbean and longitudinally considered the period 2000-2018 using grouped regression models, fixed effects models or random effects models. The Hausman test was used to choose between fixed and random effects models.
Results: The results of both the random effects models and the fixed effects models demonstrated the negative impact of economic growth on scientific production. This proves that it is necessary to state alternatives to mend and improve the state of scientific production.
Conclusion: The present study is relevant because it is one of the first to study the impact of gross domestic product on scientific production

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in Latin American and Caribbean countries from a longitudinal perspective that also allows evaluating the dynamics of both variables.

Keywords
growth, Scientific, production, data, analys

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Introduction

The Organization for Economic Cooperation and Development (OECD) reports the entry into the era of knowledge-based economies, which are strictly based on technological innovation, the use of knowledge and information and communication technologies.[1] As a result, science and technology have gained great relevance to the current economy. Throughout the years, progress in innovation and research has reached its highest peak, both in scientific productivity and in its complexity[2,3] and the idea that the scientific and technological progress of a country is the basis of economic dynamics, production growth and its expansion, is becoming more and more common and more accepted and promoted by international organizations oriented to economic development.[4] However, with the presence of COVID-19, this progress and funding have collapsed.[5] There were sharp declines in economic growth throughout the world during the first half of 2020. Several major investment banks projected negative global economic growth for 2020 of between -1% and -3% of gross domestic product (GDP), but there was a high degree of uncertainty in these figures.[6]

Between January 2019 and January 2020, growth of 2% was expected, but the latest estimates indicate that growth was below 1%. These estimates have changed due to the COVID-19 pandemic. Global stock markets declined as investors began to worry about the economic repercussions of the COVID-19 pandemic. Gross Domestic Product declined, and this pandemic cost the world more than $2 trillion by the end of 2020.[7] Although many Latin American countries have seen their economies grow over the last five years, the pandemic has been the catalyst for many sectors to explore ways to overcome it through innovation. As a result, a number of sectors have made significant progress, achieving, among other things, an important economic revival.[8]

Governments establish policies that seek to guide the development of their nations, face the structural difficulties that hinder growth options, generate opportunities in the different sectors of society, distribute the wealth generated and thus seek to achieve the highest goals that society has set for itself.[9] However, in Latin America, government financial support for research is insufficient and has generated controversy by requiring researchers to publish in high impact journals.[10]

The allocation of resources for research in Latin America is greatly disproportionate to that of developed countries, and it is evident that in Bolivia, El Salvador, Guatemala, Paraguay and Peru, the allocation of resources for research and development through public funding and private companies is not a priority for governments.[10] Peru is the Latin American country with the fewest resources for research development, specifically compared with the other members of the Pacific Alliance, which also includes Chile, Colombia and Mexico. This is reflected in the low Peruvian representation in the scientific production of the region, where only 1.04% of the scientific publications are by Peruvian authors.[11]

Regarding the number of publications, Peru has had a slight but continuous increase in spending as a percentage of GDP since 2011 and thus achieved its best result in the last years of the examined period, with 0.12% per year. Consequently, in 2017, Peru ranked seventh in scientific production in Latin America with more than 2700 studies. Mexico published more than 23,000 documents that year, and Argentina published more than 13,000 studies with considerably higher number of researchers.[12]

Like the rest of the world, in Latin America we must face the COVID-19 pandemic, which highlights the need to invest more in research. It is necessary to have a measurement system that allows us to evaluate the number of scientific publications and the impact of economic growth. These key factors involve the adoption of a solid long-term research policy focused on the allocation of economic resources for research.

Research and development expenditures include current and capital expenditures (public and private) on creative work undertaken to improve knowledge, including knowledge about humanity, culture and society and the use of knowledge for new applications. Research and development encompass basic research, applied research and experimental development. This seeks to model a scientific and technological culture that involves the collective production of scientific knowledge, interdisciplinary work and the participation of all actors in the field of scientific-technological development of the country.[13]

However, little is known about the impact of economic growth on the number of scientific publications in Latin American and Caribbean countries. Our study identifies the research problem by asking the following question: what is the impact of the GDP on the number of scientific publications in Latin American and Caribbean countries?

The result of low GDP investment in research in Latin America and the Caribbean is detrimental to innovation, compromising the development of different sectors of the economy, one of the greatest competitive advantages that one country can have over another.[14] If a country is interested in improving its competitiveness, it is essential to greatly increase investment in research and development.[15] Research aims to create knowledge, strengthen economic growth and implement public policies and social development in countries as a result of their economic development.[16]

The policies promoted by governments around the world for the financial support of research have not only boosted the resources available to universities, but have also boosted their academic quality. Evidence of this is the number of researchers working in Science, Technology and Innovation (STI) areas, as there is a record of 7.8 million scientists and engineers working in STI production. This represents an increase of 21% with respect to the number registered by UNESCO in 2007.[17] However, in Latin America, the promotion of research in national strategies to improve education, national development and scientific production led by researchers in the different countries of the region remains below the expected values, showing a high dependence on international collaboration to achieve recognition in the international scientific community.[18]

The connection between science and economic factors, such as production factors and the construction of the social fabric, was studied by Quinde-Rosales *et al.*[9] These results allowed us to establish a model that demonstrated the bidirectional nature of the GDP and expenditures in science and technology, enabling us to establish that the differences in the two variables are stable and that the expenditure generated by science and technology depends on the GDP.

The study by Giraldo-Gutierrez *et al.*[19] analyzed the impact of science, technology and innovation (STI) policies on the production and appropriation of knowledge. The results showed that despite the low investment in STI, scientific production has been increasing due to factors such as the creation of research centers and the development of research. Santina and Caregnato[20] showed that in different countries, research behaves unevenly. A few countries focus on financial resources and human resources at the internal level and external levels of natural resources and the wide diversity in the integrations of different countries to strengthen research in the countries.

Cepeda Avila *et al.*[21] indicate that scientific production has grown over the years in different Latin American countries despite the limitations; however, compared to developed countries, scientific production remains low. The authors' explanation for the increase in scientific production is that an increasing number of researchers carry out projects that culminate in publications, although their financial resources are quite scarce. Pérez and Lutsak-Yaroslava[22] indicate that scientific production in Latin America is growing and consolidating, as indicated by the increase in publications in high impact journals and the establishment of networks that stimulate the advancement of knowledge.

Vargas-Merino and Rodríguez[23] indicate that it is important to continue to increase production capacity and maintain outstanding performance in terms of impact and excellence. The real challenges are to achieve recognition of production led by researchers in these countries, generate true internal capacities for the development of quality research and decrease dependence on international collaboration.

In view of the above, this research aimed to evaluate the impact of GDP on the number of scientific publications in Latin American and Caribbean countries under pre-pandemic conditions. In this way, it will be possible to determine in the future the countries in which the pandemic had a greater impact on scientific production. Therefore, the objective of our study was to estimate the impact of economic growth on scientific production, measured as the variation in gross domestic product and the number of scientific publications in Latin American and Caribbean countries.

Methods

Type of study

Observational, explanatory, retrospective, cross-sectional and longitudinal.

Population and sample

All the countries in Latin America and the Caribbean with complete information according to the variables of economic growth and scientific production, in the period 2000-2018. These countries, in alphabetical order, are the following: Argentina (ARG), Bolivia (BOL), Brazil (BRA), Chile (CHL), Colombia (COL), Costa Rica (CRI), Ecuador (ECU), El Salvador (SLV), Guatemala (GTM), Haiti (HTI), Honduras (HND), Mexico (MEX), Nicaragua (NIC), Panama (PAN), Paraguay (PRY), Peru (PER), Dominican Republic (DOM), and Uruguay (URY).

We considered the following variables

Economic growth: gross domestic product per capita (GDP, $ at current international prices).

Scientific production: articles in scientific and technical journals.

Data collection

Data were downloaded from the open data source of the World Bank (https://datos.bancomundial.org/indicator), considering Latin American and Caribbean countries which have complete information in the period from 2000 to 2018.

Data analysis

The analysis was performed using static panel data models, considering the Latin American and Caribbean countries cross-sectionally and the period 2000-2018, longitudinally. The initially proposed models derive from the following:

$Y_{it} = \eta_{1i} + \beta X_{it} + u_{it}$

i = 1, 2, …, 18 countries t = 1, 2, …, 19 years (period 2000-2018)

Where, Y_{it} is the scientific output (in natural logarithms, lnarticles); X_{it} is the GDP per capita (in natural logarithms, lnGDP); uit, the error; η_i and β, the model parameters, with:

(1) *Pooled regression model:* unobserved heterogeneity

$\eta_i = \eta$, constant for all countries.

(2) *Fixed-effects model for panel:* includes heterogeneity for each country

η_i, i = 1, 2, …, 17, different for each country.

(3) *Random effects panel data model:* unobserved heterogeneity within the error component, as:

$\nu_{it} = \eta_i + u_{it}$

Models (1)-(3) are the so-called one-way models, and the conventional assumptions.[24,25]

Once heterogeneity among countries and among the years 2000-2018 were verified, we resorted to two-way static panel data models:

$Y_{it} = \eta_i + \delta_t + \beta X_{it} + u_{it}$

Where δ_t captures the heterogeneity associated with time (years).

The models were compared, and assumptions evaluated with appropriate tests,[24,25] using STATA v.16.[26] The Hausman test was used to decide between a fixed-effects model and a random-effects model. The estimated two-way fixed-effects model was corrected using cluster-robust estimators by country, in accordance with Hoecche's assessment of assumptions.[24]

Results

The scientific production in 18 countries of Latin America and the Caribbean, in the period 2000-2018, is shown in Figure 1. This shows that Brazil, Mexico and Argentina have been the countries with the most production, defined as the number of articles published (in neperian logarithms).[27] The X axis corresponds to country identification numbers, ordered alphabetically. The lines correspond to the average scientific production of the countries, showing different levels of production that is not captured by classical regression methods (unobserved heterogeneity). It can also be seen that scientific production has changed over time in certain countries more than in others: Argentina has maintained its production over time, and Ecuador has changed more, showing scientific production with different variance between countries.

Figure 2 shows the relationship between the impact of economic growth and scientific production, in which we can see, through the solid line, the general association and by each country of Latin America and the Caribbean. There is evidence of a positive trend. At country level, less impact is observed in comparison with Latin America and the Caribbean.

The proposed static panel data models were the following: pooled regression, fixed effects and random effects. The estimated models, shown in Table 1, confirm the expected impact of economic growth on scientific production, which is estimated to be positive, $\widehat{\beta} = 2.91256$ ($p < 0.05$) in the pooled regression model (OLS), $\widehat{\beta} = 1.77793$ ($p < 0.05$) in the fixed effects model, and $\widehat{\beta} = 1.78803$ ($p < 0.05$) in the random effects model; the coefficients of determination were 50.43%, 69.4%, and 69.4%, respectively. The first order correlations (rho) were estimated to be 0.971 and 0.967 in the fixed and random effects models, respectively. Apparently, the pooled regression model indicates a greater impact (see OLS in Figure 2), but, as we know, it does not consider differences between countries (unobserved heterogeneity).

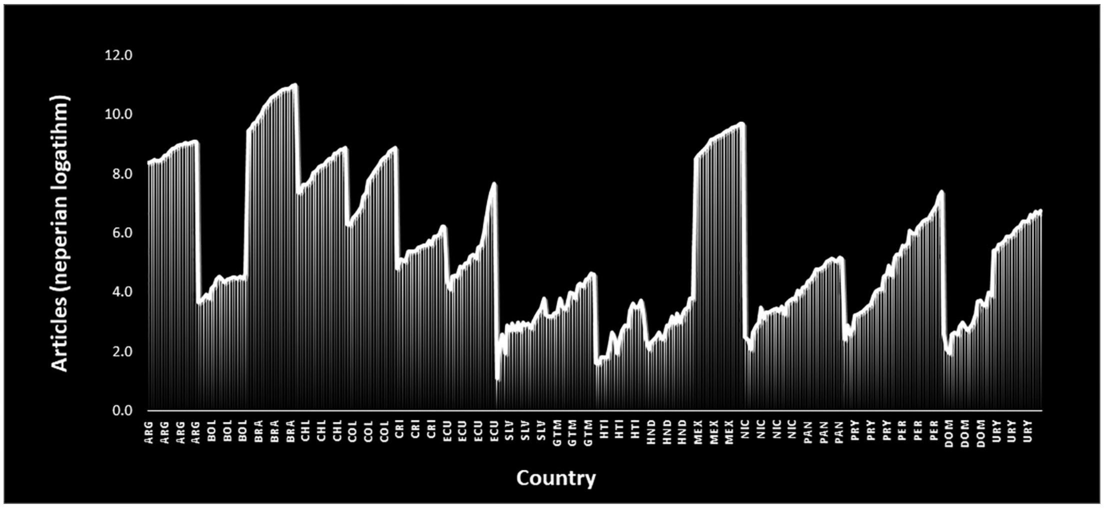

Figure 1. Scientific production in Latin America and the Caribbean, period 2000-2018. Key: Argentina (ARG), Bolivia (BOL), Brazil (BRA), Chile (CHL), Colombia (COL), Costa Rica (CRI), Ecuador (ECU), El Salvador (SLV), Guatemala (GTM), Haiti (HTI), Honduras (HND), Mexico (MEX), Nicaragua (NIC), Panama (PAN), Paraguay (PRY), Peru (PER), Dominican Republic (DOM), and Uruguay (URY).

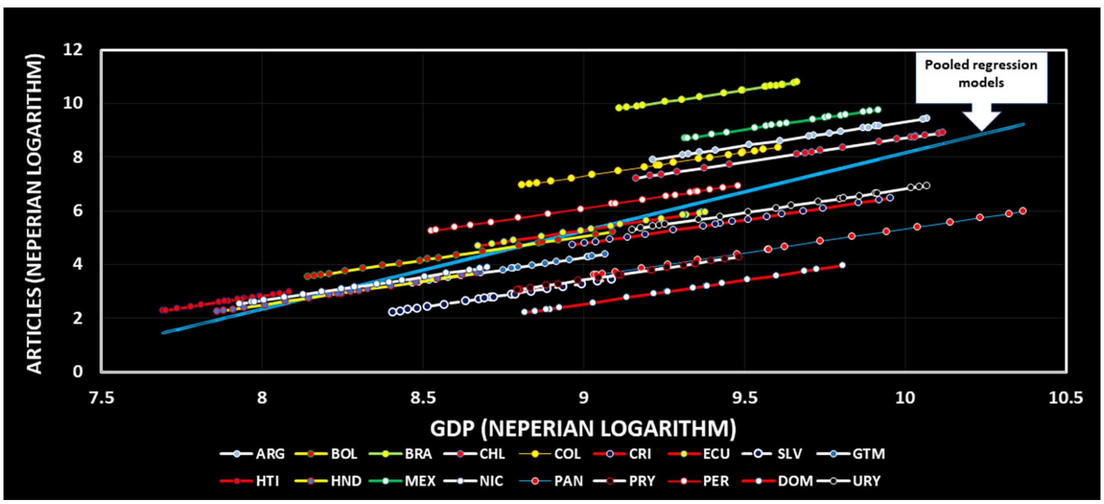

Figure 2. Impact of gross domestic product on scientific output in Latin America and the Caribbean, period 2000-2018. Pooled regression model (OLS). Key: Argentina (ARG), Bolivia (BOL), Brazil (BRA), Chile (CHL), Colombia (COL), Costa Rica (CRI), Ecuador (ECU), El Salvador (SLV), Guatemala (GTM), Haiti (HTI), Honduras (HND), Mexico (MEX), Nicaragua (NIC), Panama (PAN), Paraguay (PRY), Peru (PER), Dominican Republic (DOM), and Uruguay (URY).

Table 1. Static panel models for the impact of economic growth on scientific production in Latin America and the Caribbean, period 2000-2018.

	OLS		Fixed effects		Random effects	
lnarticles	**Coef.**	**P >|t|**	**Coef.**	**P >|t|**	**Coef.**	**P >|t|**
lnGDP	2.91256	0.000	1.77793	0.000	1.78803	0.000
cons	-20.95947	0.000	-10.66311	0.000	-10.75478	0.000
sigma_u			1.893		1.773	
sigma_e			0.327		0.327	
rho			0.971		0.967	

Table 1. *Continued*

Inarticles	OLS		Fixed effects		Random effects	
	Coef.	P >|t|	Coef.	P >|t|	Coef.	P >|t|
corr(u_i,Xb)			0.3721		0.000	
R-sq:						
within	0.5043		0.694		0.694	
between			0.515		0.515	
overall			0.506		0.506	
F (Chi)	347.920		733.090		741.720	
p	0.000		0.000		0.000	
F test that all u_i = 0: F(17.305) = 550.05			Prob > F = 0.0000			

The models were compared using various tests. In Table 1, heterogeneity between countries is evident (F = 550.05, p = 0.0000 < 0.05), unobserved by the pooled regression model. On the other hand, the Hausman test (Chi-square = 3.29, p = 0.0695 > 0.05) indicates no difference in the impacts estimated by the fixed effects model and the random effects model. Likewise, the Breusch and Pagan Lagrange multiplier test for random effects (Chi-square = 2674.65, p = 0.0000 < 0.05) indicates that the random effects model is better than the pooled regression model.

The assumptions of the fixed effects model were also evaluated. The Breusch-Pagan LM test for errors independence between countries results in its rejection (Chi-square = 790.614, p = 0.0000 < 0.05), which establish the dependence between them. First order autocorrelation was evaluated with the Wooldridge test (F = 16.683, p = 0.0008 < 0.05) and the Baltagi-Wu LBI test (rho = 0.634, F = 62.44, p = 0.0000 < 0.05), which show the presence of first order autocorrelation in both tests. The heteroscedasticity of the errors, using the modified Wald groupwise heteroscedasticity test for countries (Chi-square = 4798.87, p = 0.0000 < 0.05), indicates different variabilities between countries.

Once the heterogeneity of scientific production between countries was verified, the possible heterogeneity over time was also evaluated. Figure 3 shows a positive trend in scientific production in each country. Colombia, which in 2000 produced less than Chile and Argentina, in 2018 equaled Chile, and the production in both was close to Argentina's production. Ecuador, whose production in 2000 was lower than Costa Rica's, Uruguay and Peru, surpassed them as of 2016. In summary, average scientific production is expected to increase over time, showing temporal heterogeneity, giving rise to two-way models. The models estimated in Table 1 correspond to one-way models.

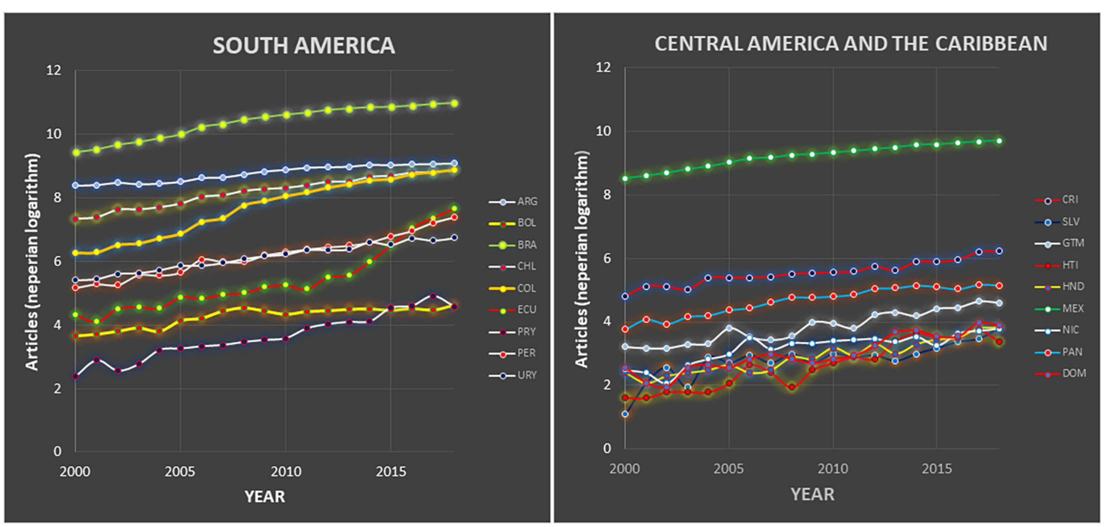

Figure 3. Scientific production in the period 2000-2018, in Latin America and the Caribbean. Key: Argentina (ARG), Bolivia (BOL), Brazil (BRA), Chile (CHL), Colombia (COL), Costa Rica (CRI), Ecuador (ECU), El Salvador (SLV), Guatemala (GTM), Haiti (HTI), Honduras (HND), Mexico (MEX), Nicaragua (NIC), Panama (PAN), Paraguay (PRY), Peru (PER), Dominican Republic (DOM), and Uruguay (URY).

Table 2. Static two-way panel models for the impact of economic growth on scientific production in Latin America and the Caribbean, period 2000-2018.

	Fixed effects		Random effects	
lnarticles	**Coef.**	**P >|t|**	**Coef.**	**P >|t|**
lnGDP	-0.55548	0.002	-0.36630	0.041
Year				
2001	0.08722	0.318	0.08418	0.349
2002	0.16986	0.052	0.16436	0.068
2003	0.29116	0.001	0.27904	0.002
2004	0.46847	0.000	0.44512	0.000
2005	0.64465	0.000	0.60876	0.000
2006	0.83943	0.000	0.78831	0.000
2007	0.89081	0.000	0.82611	0.000
2008	1.02318	0.000	0.94895	0.000
2009	1.09592	0.000	1.02269	0.000
2010	1.21524	0.000	1.13193	0.000
2011	1.29620	0.000	1.20052	0.000
2012	1.44898	0.000	1.34781	0.000
2013	1.52897	0.000	1.41751	0.000
2014	1.68848	0.000	1.56885	0.000
2015	1.75608	0.000	1.63211	0.000
2016	1.89814	0.000	1.76478	0.000
2017	2.07667	0.000	1.93340	0.000
2018	2.12146	0.000	1.97212	0.000
cons	9.43075	0.000	7.78788	0.000
sigma_u	2.70303		1.77393	
sigma_e	0.26128		0.26128	
rho	0.99074		0.97877	
corr(u_i,Xb)	-0.38620		0.00000	
R-sq:				
within	0.8152		0.8145	
between	0.5151		0.5151	
overall	0.0283		0.0029	
Wald $Chi^2(19)$	70.80		1256.99	
Prob > Chi^2	0.00000		0.0000	
F test that all u_i = 0: F(17.305) = 850.61			Prob > F = 0.0000	

The two-way estimator models are shown in Table 2, including fixed-effects and random-effects panel data models. Compared to 2000, scientific production was differentiable in almost all years, with the exception of 2001 and 2002, when it was similar, both in the fixed effects model ($p = 0.318 > 0.05$ and $p = 0.052 > 0.05$, respectively) and in the random effects model ($p = 0.349 > 0.05$ and $p = 0.068 > 0.05$, respectively). Heterogeneity between countries is ratified ($F = 850.61$, $p = 0.0000 < 0.05$), and temporal heterogeneity is accepted (Chi-square = 169.59, $p = 0.0000 < 0.05$) through an additional test. The coefficients of determination improved, to 81.52% in the fixed effects model, and 81.45% in the random effects model.

The observed heterogeneity in the estimated two-way panel data models shows that the estimated impact of economic growth on scientific production, contrary to what was expected, is negative $\widehat{\beta} = -0.55548$ ($p = 0.002 < 0.05$) in the fixed effects model and $\widehat{\beta} = -0.36630$ ($p = 0.041 < 0.05$) in the random effects model.

The Hausman test establishes differences in the estimation of the parameters between both two-way models (Chi-square = 20.87, p = 0.0000 < 0.05), including differences in the impact of economic growth, indicating that the fixed effects model is adequate. Likewise, the Breusch-Pagan LM test for errors independence between countries showed their dependence (Chi-square = 643.664, p = 0.0000 < 0.05), and the modified Wald groupwise heteroscedasticity test (Chi-square = 2520.56, p = 0.0000 < 0.05) confirmed their presence. This situation led us, following Hoecche, to resort to the use of robust estimators by clusters to correct these drawbacks.

The two-way fixed effects panel data model with robust estimators corrects the standard errors of the estimators and modifies their significance level. In general, the model maintains the similarity of scientific production in 2001 and 2002 compared to 2000, and the differences in subsequent years.

As for the impact of economic growth on scientific production, estimated by the robust method, although it continues to be negative ($\hat{\boldsymbol{\beta}} = -0.55548$, $s_{\hat{\beta}} = 0.33876$), it does not reach statistical significance ($p = 0.119 > 0.05$), which indicates the absence of such impact, and not the expected positive impact in Latin American and Caribbean countries included in the study.

Discussion

The aim of this study was to evaluate the impact of economic growth on scientific production in Latin American and Caribbean countries in order to collect important basic data to respond to the problems of low scientific production due to economic and structural causes faced by the region. This is important because one of the main objectives of the countries' spending on research is to achieve higher-level scientific results that can improve the population's standard of living.[28]

One of the main findings was the absence of impact of economic growth on scientific production by the robust method, since this result differs from that reported by many studies that found a relationship between both variables.[29–33] However, it is likely that this difference is due, in the first place, to the characteristics of the study itself and to the fact that the evidence reported on the relationship between GDP and scientific production are, for the most part, specialized studies that include publications worldwide and do not cover scientific production in general.

For example, Jaca *et al.*[33] published a global bibliometric analysis of publications on vaccine refusal in the last 45 years, finding a relationship between scientific productivity and GDP. In addition, Latin American and Caribbean countries had the lowest production rates compared to the United States and European countries, which has also been reported by Ibañez-Marti.[34] Another example is reported by Senel in 2020,[35] who found an association between GDP and scientific productivity in the countries, in addition to a low contribution by Latin American and Caribbean countries in the area of immunology. In contrast, Ronda-Pupo reported a growth in global scientific production in the Latin American and Caribbean region[36] although, when productivity is analyzed by specialties or areas of knowledge and compared with the rest of the world, this region is below the average.[37]

The impact of economic growth on scientific production in Latin America and the Caribbean for the period 2010-2018 did not differ broadly among countries. Economic growth was maintained in several countries; however, it mainly decreased in Brazil, Chile, Ecuador, Panama and Peru, and it decreased from 2012-2013 in Colombia and Venezuela. Latin America and the Caribbean continue to be a region with average or lower-than-average performance for most knowledge indicators and most growth components.[38] This may be due to its primarily product-based economy that is focused on the export of materials and unprocessed goods and has little added value from knowledge and technology, which creates a development gap in advanced technology that affects its economy. No less important is the conduct of research that does not respond to the priorities of policy-makers and that is not aligned with the needs of those responsible in the real world.[39]

In terms of scientific production, Brazil and Mexico were the frontrunners, which coincides with what has been reported by other authors, such as Tibaná G.,[40] Ronda-Pupo[36] and Ibañez-Marti.[34] This leadership on the part of Brazil is probably due to the fact that, according to Tibaná, it is the only country in the region with an investment of more than 1% of GDP in scientific research. Moreover, with the exception of Brazil, there are few countries in Latin America that promote research and development activities with an intensity comparable to that recorded in developed countries.[41]

Besides being the country with the highest growth rate, this investment in research allows Brazil to have more than 400 journals in Scopus and to be ranked 15th in the world. It is worth mentioning that the areas with the highest scientific production correspond to ecology, technology and health.[42] However, Ozsoy and Demir[43] reported in 2017 that Brazil is the country with the highest scientific production on bariatric surgery worldwide, leaving behind countries such as the United States or China, providing strong evidence of inequality in science in the region.

This could be indicative enough to conclude that science in the region is marked by a strong inequality, led by few countries, characterized by low regional integration[20] and with a high intercontinental participation led by Brazil.[44] In the case of Mexico, 68.13% of the articles that received funds from CONACYT were published in restricted-access journals. This means that a large part of the Mexican population does not have access to the results of research financed with state resources. According to economic theory, this restricted circulation of knowledge can undermine the advancement of basic science and innovation.[45] On the other hand, scientific production in Brazil remained the same, despite the fact that in recent years, Brazilian scientists have faced a drastic reduction in financial support for research and graduate programs.[10] According to Jarrín-V *et al.,*[28] the efficiency with which a country assimilates investment in research and development depends on (and is limited by) its installed capacities (scientific infrastructure, human resources, programs and laws, *etc.*). Argentina, Colombia and Chile were the countries with the highest scientific production in the 2010-2018 period. However, Colombia, Costa Rica, Chile, Ecuador, Guatemala, Honduras, Paraguay and Peru also showed consistent growth, though to a lesser degree than the leading countries. Although Latin America has increased its number of scientists and research institutions in recent years, the gap between developed countries and Latin American countries is alarming.[37] The primary importance of science and technology for the development of a nation remains unrecognized. The main factors that contribute to low scientific productivity are limited access to grant opportunities, inadequate budgets, deficient levels of infrastructure and laboratory equipment, the high cost and limited supply of reagents and the inadequate salaries and personal insecurity of scientists. Political and economic instability in several Latin American countries has translated into a lack of the types of long-term goals that are essential for the development of science. In Latin America, science is not an engine of the economy.[46]

The results in this study of the panel data regression were used to classify countries according to their assimilation of investment in research over time.[45] The role of the university in training professionals and generating knowledge through the development of research is key to a country's economic growth. Therefore, at the university level, there must be an appropriate economic and institutional approach, adequate information infrastructure, a solid base of human capital and an efficient national information system.[47,48]

Our study proposes a useful model panel data models that consider the differences in the impact of economic growth on scientific production in countries, fixed or random. This model makes it possible, with large samples and few assumptions, to estimate functional relationships between two variables that provide evidence of the importance of science and technology for academic, economic and social development.[49–52]

Although the purpose of this research was to show a broad panorama of the countries of Latin America and the Caribbean, it is important to note that each nation has intrinsic characteristics that can affect its economic growth and its scientific production. However, all of them require the implementation of national policies that converge into a cooperative process that transforms knowledge into wealth and makes these countries more competitive against developed economies in terms of private sector participation in research and development activities. This requires policies that encourage private investment in an environment that is more favorable to new long-term investments. As most of the investment in research and development at present comes from the public sector, it is strategic to convert private resources into knowledge in the effort to consolidate innovation potential.

The present study has some limitations: (1) only countries with complete information in the World Bank's open database were included, so many countries were omitted, which can generate important losses of information; (2) measuring the scientific production of a country can be complicated since it can be understood differently according to personal perception. In addition, the impact of such an indicator has not been taken into account, such as the H index or type of journals, which could lead to different conclusions, since although there may be greater scientific production in a given time interval, this does not necessarily mean that there is greater impact of such publications. However, this is one of the first studies that seeks to relate economic growth and scientific production, and therefore provides important information that will serve as a basis for subsequent studies.

Conclusion

The present study is relevant because it is one of the first to study the impact of gross domestic product on scientific production in Latin American and Caribbean countries from a longitudinal perspective that also allows evaluating the dynamics of both variables. It was found that Brazil and Mexico lead the scientific productivity indexes in the region, while countries such as Peru, Chile and Uruguay have been increasing their scientific production but remain below the average in comparison with the leaders in the region and the world. However, it is necessary to carry out more studies on the subject since scientific production can be studied from different approaches including indicators such as the impact of scientific publications, the type of journal where the countries of the region publish the most and the level of international and intercontinental contribution in these publications. Therefore, a better understanding of the subject will allow better decisions to be made for a better management of national resources directed to research and development.

Data availability statement

Underlying data

Zenodo: Oriana Rivera-Lozada, Judith Soledad Yangali-Vicente, Pablo Alejandro Millones-Gòmez, Carlos Alberto Minchón Medina, & Tania Valentina Rosales-Cifuentes. (2022). Impact of economic growth on scientific production in Latin America and the Caribbean based on panel data analysis. https://doi.org/10.5281/zenodo.7272492.[27]

This Project contains the following underlying data:

- Growth economic.xlsx

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Open Peer Review

Current Peer Review Status: ? ✗ ?

Version 1

Reviewer Report 07 July 2023

https://doi.org/10.5256/f1000research.140633.r175523

?

Paul Owusu Takyi

Department of Economics, Kwame Nkrumah' University of Science and Technology, Kumasi, Ghana

General Comments

The article studies the impact of economic growth on scientific production in Latin America and the Caribbean based on panel data analysis. In general, the topic and premise of the study is interesting and timely. My main concerns related to the methodology and empirical analysis. See detailed comment below.

Specific comments

1. What is the overall economic growth in the region under study? What are the scientific production levels in the region? Some correlation analysis between these two variables need to be provided in the introduction section to create a research problem for the study.

2. The authors failed to discuss the theoretical model or theory that underpins their study. I that suggest the authors discuss the theoretical model that gave rise to the empirical model they estimated.

3. They employed a static panel model in their study but failed to provide a justification for it as well as the advantages of such a model over dynamic panel model.

4. The natural log of GDP does not directly measure economic growth as the authors use in their study. Rather, it is the log differences. I suggest that the author use the later to measure economic growth in their estimation

5. Having only one explanatory variable in the model used is not standard. The authors need to control for other factors could affect scientific production. For example, the level of education, expenditures on R&D etc.

6. The output from scientific production identifies new technology and provides policy

recommendations for the governments. All of these feed into the production capacity of a country which could affect overall economic growth. Thus, there is a possible reverse causality between economic growth and scientific production leading to a potential endogeneity problem. How did they authors deal with this problem? I suggest that the authors explore other models that handles this problem (e.g. GMM, panel fixed effect with instrumental variables etc).

7. The equations in the text need to be numbered.

8. The results in Table 2 indicate that lnGDP significantly reduces scientific production. What are the possible explanations for this finding?

9. In the discussion section, the authors need to discuss the possible channels through which economic growth affect scientific production.

10. The conclusion section lacks policy implications from the results. This section needs to be strengthened.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
No

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Development finance, macroeconomics, applied econometrics, monetary economics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 04 July 2023

https://doi.org/10.5256/f1000research.140633.r175528

Lorenzo Zirulia
Associate Professor of Economics, University of Milan, Milan, Italy

The paper "Impact of economic growth on scientific production in Latin America and the Caribbean based on panel data analysis" investigates the empirical relationship between scientific publications and GDP growth rates. It finds no impact of economic growth on scientific production using robust methods. The theme is important, and overall the paper is well written. However, I have two main concerns I can list as follows.

1. Conceptually, I cannot see in clear way the mechanism through which economic growth should impact publications. There is some reference to the role of political stability, but vague. I would like to see an empirical model stating explicitly a knowledge production function, whose list of arguments would surely include R&D expenditures as primary input and other mediators. However, what would be the role of GDP growth? it is unclear to me. As it is now, GDP is apparently capturing a bunch of explanatory variables.

2. I am also in trouble with the assumption of a contemporaneous relationship between the X and the Y. If one buys the idea that GDP growth is in fact mainly capturing R&D growth, then it would natural to assume a certain lag between R&D as input and publications as output. The non significance can be related also this issue.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Economics of science and innovation

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 19 April 2023

https://doi.org/10.5256/f1000research.140633.r165660

?

Ioan Batrancea
Faculty of Economics and Business Administration, Universitatea Babes-Bolyai, Cluj-Napoca, Cluj County, Romania

General Comments
From my point of view, it is a very interesting topic and simultaneously it seems that to the best of my knowledge is the first empirical study to determine the impact of economic growth on scientific production, measured as the variation in the gross domestic product and the number of scientific publications, in Latin American and Caribbean countries. The findings of both the random effects models and the fixed effects models demonstrated the negative impact of economic growth on scientific production. This study is relevant because it is one of the first to study the impact of gross domestic product on scientific production in Latin American and Caribbean countries from a longitudinal perspective that also allows evaluating the dynamics of both variables.

The paper contains the following sections: *Introduction, Methods, Results, Discussion and Conclusion*.

However, I find some recommendations:

1. There is a mistake in the key words and I propose the following order: Growth, Scientific production, Data, Analysis

2. The abstract must contain the main purpose of the paper, the research method used in the research and the main contributions.

3. It would be very useful to add in the "*Introduction*" section the purpose, objectives and hypothesis of the research. I consider that a weak point of the paper is that the authors did not show the novelty of the paper compared to other works. That is why, I consider that the introduction should specify the novelty of the paper compared to other papers published in this area.

4. The research is well based on science and the results are in agreement with the theoretical part. From my point of view, the paper is original and the topic addressed brings added value to the specialized literature regarding the influences of economic growth on scientific production. The paper is well written and easy to read.

5. At the same time, the authors are required to present Descriptive Statistics, Correlation matrix with all tests and indicators: standard deviation, Jarqe-Berra, Skewness and Kurtosis interpretation, Jarqe-Berra with probabilities analysis, etc.

6. It is important to present the VIF test on multicollinearity between independent variables. Heteroskedasticity and Endogeneity tests are also important in this study. All these aspects that are not found in the paper represent weaknesses of the research.

7. At the same time, I consider that the conclusions part of the work should be expanded with policy implications.

8. I think that the literature needs to be improved with other works, referred to economic growth. I considered that the works cited in this paper are few and therefore the authors should expand the list of references. That is why I recommend the authors to refer to other recent works indexed in Web of Science. I suggest the authors consider the following articles, all are based on a panel econometric analysis and we have asked the authors to extend the paper with such an analysis. I suggest that the authors cite papers published in Web of Science Journals, such as:
    1. Batrancea L.M. (2021) An Econometric Approach on Performance, Assets, and Liabilities in a Sample of Banks from Europe, Israel, United States of America, and Canada. Mathematics, 9(24):3178. https://doi.org/10.3390/math9243178.
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    3. Batrancea, L.M., Rathnaswamy, M.M., Rus, MI. *et al.* Determinants of Economic Growth for the Last Half of Century: A Panel Data Analysis on 50 Countries. *J Knowl Econ* (2022). https://doi.org/10.1007/s13132-022-00944-9
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    8. Brueckner, M. Infrastructure and economic growth. *J. Risk. Financ. Manag.* **2021**, *14*, 543. https://doi.org/10.3390/jrfm14110543

9. The conclusions at the end of the paper should be expanded showing the economic policy implications of the research results.

In conclusion, the article should be improve. It should also be enhanced with a review of the literature adequate to the subject and a broader interpretation and commentary of the research results.

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Is the work clearly and accurately presented and does it cite the current literature?
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Is the study design appropriate and is the work technically sound?
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Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
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Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Finance, Financial Analysis, Econometrics

I confirm that I have read this submission and believe that I have an appropriate level of

expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.