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Economic and Social Drivers of Scientific Productivity in Latin America: Evidence from a Panel Quantile Regression

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Abstract

The scientific production of a country drives economic, technological, and social development by generating knowledge, fostering innovation, and enhancing competitiveness. It also contributes to addressing global challenges and strengthening both education systems and international cooperation. Given its impact on national sustainability and progress, this study analyzes the influence of key variables-globalization, civil liberties, R&D expenditure, and GDP per capita-on the volume of scientific publications across 15 Latin American countries between 2001 and 2019, using the panel quantile regression method. The findings reveal that scientific production, measured by the number of published articles, is positively influenced by GDP per capita, globalization, and civil liberties. Furthermore, the study highlights the importance of R&D expenditure, both public and private, in knowledge generation. This research suggests that policymakers should promote economic development through the region's scientific capabilities to foster sustainable development and technological progress in Latin America.

Keywords: Scientific Output, R&D, Human Capital, Structural Change.

Introduction

The role of research and development (R&D) in economic growth and innovation has been widely documented from various perspectives (Tung and Hoang, 2024). From a theoretical standpoint, contributions by Romer (1990, 1993) and Lucas (2009), highlight human capital as a fundamental driver of long-term economic development through its contribution to R&D. This is reinforced by empirical evidence from Anand et al. (2021), who assert that investment in R&D not only promote the creation of new knowledge but also enhances a country's ability to assimilate and utilize external knowledge effectively.

Currently, technological advancement is considered the factor that accelerates the acquisition of new information, technologies, products, and services that foster a new development model for nations (Aiello and Cardamone, 2008; Inekwe, 2015; Choi and Yi, 2018; Ervits, 2021; Wan et al., 2022). This demonstrates that the relationship between R&D investment and economic

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growth is shaped not only by domestic conditions but also by interregional and global factors. (De Noni and Ganzaroli, 2024, 2018; Crescenzi and Jammario, 2018; Rodríguez-Pose and Crescenzi, 2008). In this context, globalization emerges as a positive and relevant factor in shaping scientific production, as it enables the cross-border flow of knowledge, financial resources, and human capital (Wang et al., 2019; Li et al., 2021).

However, globalization also presents economic and social challenges (Woo & Jun, 2020; Le et al., 2022). Various studies emphasize that in an interconnected world, civil liberties are essential in fostering creativity and the free exchange of ideas, both of which are vital for scientific research. Mobile researchers, for instance, benefit from access to transnational networks and exposure to information unavailable in their countries of origin (Baruffaldi et al., 2020). According to Kahn and MacGarvie (2016) and Shen (2024), such mobility facilitates the establishment of enduring connections between home and host institutions, reinforcing the argument that ‘greater knowledge of distant sources is associated with greater idea generation and creative achievements’ (Gu et al., 2024).

This scenario has led to an increasing number of collaborations scientific publishing, where knowledge creation processes have become increasingly internationalized (Varga, Pontikakis, and Chorafakis, 2014). Given the strong correlation between GDP per capita and the number of scientific output in a nation, many scholars regard this economic indicator as a proxy for national development (Björk et al., 2018). Countries with higher scientific publication rates generally exhibit higher income levels and greater capacity to invest in research infrastructure and scientific tools (Gómez-González et al., 2019).

Public investment in R&D also plays a central role in expanding knowledge production, particularly in contexts where private research funding is scarce (Shaddady, 2022; Abrigo & Love, 2021). According to Abrigo and Love (2021), there is a close and direct relationship between public R&D expenditure and scientific production in OECD countries. Similarly, Mokyr et al. (2015) indicate that public R&D expenditure in Europe is positively correlated with both economic productivity and scientific knowledge production. Similarly, Hurtado et al. (2024) further support the existence of a bidirectional causal relationship between the number of researchers and economic development, suggesting that as countries develop economically, their research output also increases.

This research aims to analyze the impact of civil liberties, globalization, and GDP per capita on the scientific output of Latin American region (Khattak et al., 2023). First, it introduces a focused analysis of how civil liberties and globalization influence scientific production in the Latin American context. Second, it presents empirical evidence for the Latin American region, where research on this subject remains limited and tends to focus more on R&D investment than on publication outcomes. Third, a quantile analysis is proposed, contributing to the discussion and relevance of implementing public policies according to the conditions of each country in the study variables.

The following sections present a comprehensive analysis of the factors influencing the production of scientific articles in Latin America. The methodological section outlines the data sources, variables, and analytical techniques employed. The results section shows the main findings, highlighting significant trends and correlations. These findings are then contextualized and discussed in relation to existing literature. The paper concludes with a synthesis of the main insights and provides policy recommendations and suggestions for future research,

Theoretical Framework

Methods and Materials

Science is widely acknowledged as a critical engine of economic growth. As such, individuals and institutions continually evaluate the costs and benefits of research activities in their efforts to access funding and solidify their reputations (Stephan, 2012). A comprehensive study by Kumar et al. (2016) explored the relationship between research output and economic development in China and the United States, finding a positive association between the number of scientific publications per worker and labor productivity. Similarly, Charlot et al. (2015) found strong complementarity between R&D investment and human capital across 169 European Union regions, affirming that research is fundamental to both short – and long-term economic progress.

In this context, understanding the variables that influence researchers' performance is thus essential in addressing existing development challenges (Bilbao-Osorio and Rodríguez-Pose, 2004; Furkova and Chocholata, 2017). The literature identifies globalization as one of the key factors in the number of scientific output, as it facilitates the exchange of knowledge and technological resources across borders (Wang et al., 2019). Several studies have employed the globalization index to examine this relationship and have consistently found a positive correlation between globalization and the number of scientific articles produced by country (Li et al., 202; Cai & Luo, 2021; Chen et al., 2021; Wang et al., 2019).

A major benefit is the increased interconnectivity among countries, which encourages international scientific cooperation (Gui et al., 2019) through policies associated with the international mobility of researchers, as they are important producers and carriers of information (Netz et al., 2020). This process of research mobility generates an increasing number of interregional collaborations in the creation of scientific articles (Varga, Pontikakis, and Chorafakis, 2014). This is considered beneficial for host countries (Scott, 2015) as well as for home countries, as it facilitates the circulation and transfer of knowledge between nations (Robinson-García et al., 2019; Shen et al., 2022). However, the internationalization of research also brings potential drawbacks, including the neglect of locally relevant topics, particularly in peripheral regions (Mosbah-Natanson & Gingras, 2013).

Civil liberties also exert a significant influence on scientific productivity (Mousseau & Mousseau, 2023). For example, fundamental freedoms – such as freedom of thought, expression and access to information – are indispensable for scientific inquiry (Polak, 2017; Hurtado et al., 2024). When these conditions are upheld, researchers can freely explore and develop their ideas, leading to a greater number of scientific publications (Mashhood & Siddiqui, 2021; Elveren & Duzgun, 2020). Other authors, such as Kapoor et al. (2018), affirm that the dissemination of research results can be influenced freedom of the press and transparency in information access, inspiring other researchers to investigate related topics.

Another widely discussed determinant of scientific output is GDP per capita. Numerous studies have identified a strong positive correlation between GDP per capita and the volume of scientific publications (Abramo et al., 2021; Rafols et al., 2021; Lopez-Ornelas et al., 2019; Alshahrani et al., 2018; Björk et al., 2018). Countries with higher GDP per capita typically have greater financial capacity to invest in research infrastructure, technology, and human capital (Gómez-González et al., 2019). These results align with Coccia's (2019), who argues that nations should focus on strengthening their economies to promote the advancement of science and technology,

with GDP per capita being a determining factor in the generation of scientific knowledge. However, the advancement of this relationship depends on both the quantity (volume of research) and the quality (impact) of the research, influenced by global and national economic conditions (Onyancha, 2020).

National economic development also affects the government's final expenditure, which also significantly influences the number of scientific articles published by country (Shaddady, 2022). The study by Gokmenoglu et al. (2020) and Mokyr et al. (2015) revealed a significant positive correlation between public R&D expenditure and the number of scientific articles produced. According to Abrigo & Love (2021) R&D investment significantly influences scientific production in OECD countries, with a stronger effect observed in low-income countries where private R&D investment is limited. Conversely, Li et al. (2019) found that in China, public R&D spending was more strongly linked to corporate than university research output.

Consequently, governments must allocate R&D resources strategically to maximize their influence on scientific production (Agezew, 2024). It has been determined that countries with higher GDP can allocate more funds to research and development, providing researchers with the necessary resources to conduct impactful studies, have better infrastructure and access to advanced technology, and often have more opportunities for international collaboration (Esparza et al., 2024).

In summary, scientific productivity plays a crucial role in economic development, driven by a variety of factors, including government R&D investment, globalization, civil liberties, and GDP per capita. The reviewed literature shows that there is a positive relationship between research and globalization. Additionally, the efficient allocation of resources for science and technology by governments and the private sector is crucial to strengthening the research capacity of countries and, consequently, the number of scientific publications. However, these dynamics also present challenges, such as the risk of neglecting local issues in favor of global interests. In this context, understanding the factors that influence scientific production is fundamental to designing strategies that enhance its impact on economic and social development.

Data, Variables, and Descriptive Statistics

The statistical data employed in this study were obtained from multiple reputable sources. Economic indicators such as GDP per capita and government final expenditure were sourced from the World Bank's World Development Indicators (WDI, 2020). Information on scientific output, measured by the number of published documents, was drawn from the SCImago Journal & Country Rank database (2020). Globalization metrics were collected from the KOF Globalization Index (2021), developed by Gygli et al. (2019), while data on civil liberties were obtained from Freedom House (2021). The panel dataset comprises 15 Latin American countries observed over the period 2001 – 2019.

Variable		Unit	Symbol	Data Sources
Dependent variable	Number of published documents	Articles	PUB	Scimago
Independent variable	GDP per capita	Constant 2015 USD	GDP	WDI

	Globalization index	index	GI	KOF
	Civil Liberties	Index	CIV	Freedom House
	Government's expenditure	final Constant 2015 USD	GOV	WDI

Table 1. Description of Variables and Data Sources

Source: Author's elaboration

On the other hand, Table 2 presents the descriptive statistics for the series. The dataset constitutes a perfectly balanced panel, with a total of 285 observations corresponding to 15 countries over 19 years ($T = 1, 2, \dots, 19$) and 15 countries ($i = 1, 2, \dots, 15$).

Variables	logPUB	logGDP	logGI	logCIV	logGOV
Mean	6.384	8.559	4.100	0.930	22.942
Std. Dev.	2.381	0.626	0.117	0.387	1.842
Min.	1.098	7.159	3.747	0	18.721
Max.	11.461	9.621	4.347	1.609	26.613
logPUB	1				
logGDP	0.697***	1			
p-value	0.000				
logGI	0.591***	0.641***	1		
p-value	0.000	0.000			
logCIV	-0.118*	0.548***	-0.398***	1	
p-value	0.022	0.000	0.000		
logGOV	0.949***	0.611***	0.478***	0.037	1
p-value	0.000	0.000	0.000	0.474	

Table 2. Descriptive Statistics

Source: Author's elaboration with SCIMAGOJR (2020) data, World Bank (2020), KOF (2021) and Freedom House (2021).

Econometric Techniques

This study employs a panel quantile regression model to examine the impact of economic growth, globalization, civil liberties, and foreign direct investment (FDI) on the number of researchers in Latin America. The use of quantile regression enables the analysis of the conditional distribution of the dependent variable, allowing for the capture of heterogeneous effects across countries with different levels of scientific output. Unlike traditional linear regression models – which estimate average effects and may result in coefficient overestimation or underestimation- quantile regression provides a more comprehensive insight of the relationships between variables across their entire distributios. This methodological approach was originally introduced by Koenker and Bassett (1978) in their foundational work. The generalization of the median to other quantiles can be represented as follows:

$$Q_{yi}(\tau | x_i) = x_i^T \beta_\tau \tag{1}$$

To account for both unobserved heterogeneity and conditional heterogeneity across countries, the study adopts a pane quantile fixed effects specification. This model formulation allows for robust estimation of covariate effects at various points of the conditional distribution, controlling for country-specific characteristics that remain constant over time. The panel quantile fixed effects regression can be represented as follows:

$$Q_{yi}(\tau_k | \alpha_i x_{it}) = \alpha_i + x'_{it}(\tau_k) \quad (2)$$

However, traditional fixed effects models may assume linear expectations, which are unsuitable for quantile estimations. To address this, Koenker (2004) developed a penalized quantile regression method that treats unobserved individual effects as parameters to be estimated jointly with covariate coefficients. This approach minimizes computational challenges by incorporating a penalty term into the parameter estimation process, which can be calculated as follows:

$$\min \sum_{k=1}^K \sum_{t=1}^T \sum_{i=1}^N w_k P_{\tau k} (y_{it} - \alpha_i - x'_{it} \beta(\tau_k)) + \lambda \sum_I |\alpha_I| \quad (3)$$

In the previous equation, the sample of countries (N) is represented by I ; similarly, the number of observations is denoted by T for countries, K represents the quantile index, while the explanatory variable matrix is given by x , $P_{\tau k}$ denotes the quantile loss function, and W_k is the weight for the k th quantile used in estimating the fixed effects. Additionally, λ represents the adjustment parameter used to improve the estimation of β and reduce individual effects to zero. The quantile function specification for τ for the current study variables can be expressed as follows:

$$Q_{yi}(\tau | \alpha_i, \xi_t, x_{it}) = \alpha_i + \xi_t + \beta_{1\tau} GDP_{it} + \beta_{2\tau} GI_{it} + \beta_{3\tau} CIV_{it} + \beta_{4\tau} GOV_{it} \quad (4)$$

Where i represents the units of analysis (countries), t denotes the time periods (years), y_{it} represents the indicator for the number of researchers, GDP stands for economic growth per capita, GI represents globalization, CIV denotes civil liberties, and FDI refers to foreign direct investment.

Results

The results begin with the cross-sectional dependence test using the CD statistic proposed by Pesaran (2004). As shown in Table 2, the null hypothesis of cross-sectional independence is rejected for all variables, indicating a significant degree of interdependence among the countries analyzed. This is further confirmed by the CD strength test, which reinforces the robustness of the cross-sectional associations.

Variables	logPUB	logGDP	logGI	logCIV	logGOV
CD-test	48.21***	44.227***	46.128***	4.598***	49.06***
Weak CD-test	50.944***	51.230***	51.232***	44.368***	51.234***

Table 3. Cross-Sectional Dependence Tests

Notes: The CD-test performs the null hypothesis of cross-sectional independence. The test statistical follows the normal standard distribution $N(0, 1)$. *** denotes significant at the 1% level.

Source: Author's elaboration with SCIMAGOJR (2020) data, World Bank (2020), KOF (2021) and Freedom House (2021).

To assess the stationarity properties of the variables, the CIPS unit root test by Pesaran (2007) was employed. This method accounts for cross-sectional dependence, enhancing the reliability of the test. The results (Table 4) show that all variables are non-stationary in levels but become stationary after first differencing, suggesting they are integrated of order one, I(1). This finding validates the use of cointegration techniques to analyze long-term relationships among the variables.

Additionally, it is important to highlight that the application of the CIPS test provides additional robustness to the analysis, as it considers possible correlations between cross-sectional units. This ensures that the conclusions obtained about the stationarity of the series are more reliable and accurate. Confirming that the variables are I(1) allows for the use of cointegration techniques to explore long-term relationships between them.

Variable		CIPS	
		Without trend	With trend
logPUB _{i,t}	Levels	-2.174*	-2.181
	First difference	-4.964***	-5.013***
logGDP _{i,t}	Levels	-2.034	-1.873
	First difference	-2.957***	-3.081***
logGI _{i,t}	Levels	-2.277***	-2.999***
	First difference	-4.741***	-5.026***
logCIV _{i,t}	Levels	-1.502	-2.055
	First difference	-3.370***	-3.575***
logGOV _{i,t}	Levels	-1.532	-2.044
	First difference	-4.124***	-4.457***

Table 4. Unit Root Test in First Difference

Notes: *** denotes significant at the 1% level.

Source: Author's elaboration with SCIMAGOJR (2020) data, World Bank (2020), KOF (2021) and Freedom House (2021).

The Westerlund (2005) cointegration test was then applied to determine whether a long-run equilibrium relationship exists among the variables. Table 5 presents the results under two model specifications – with and without cross-sectional averages – and includes both trend and no-trend options. Across all scenarios, the test statistics confirm the presence of cointegration. This implies that a stable long-run relationship connects the variables over time, regardless of cross-sectional dependence.

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Variance ratio	cross-sectional averages				with cross-sectional averages			
	without time trend		with time trend		without time trend		with time trend	
	Statistic	p-value	Statistic	p-value	Statistic	p-value	Statistic	p-value
test some panels	-0.9331	0.1754	-2.013**	0.022	-1.344**	0.089	-2.483**	0.006
test all panels	-1.2846	0.0995	-2.377**	0.009	-1.555	0.060	-2.605**	0.005

Table 5. Westerlund's (2005) Cointegration Test Results

Note: *** denotes statistical significance at 0.01%

Source: Author's elaboration with SCIMAGOJR (2020) data, World Bank (2020), KOF (2021) and Freedom House (2021).

To examine distributional properties, normality tests were conducted using the Shapiro-Wilk and Shapiro-Francia methods. As shown in Table 6, the p-values for all variables fall below 1%, rejecting the null hypothesis of normality. These results are further supported by the Q-Q plots in Figure 2, where deviations from the reference line indicate that none of the variables follow a normal distribution.

Variable	Skewness	Kurtosis	Shapiro-Wilk test		Shapiro-Francia test		Obs
			stat	Sig.	stat	Sig.	
logPUB	0.220	2.025	0.965	0.000	0.967	0.000	375
logGDP	-0.273	2.124	0.966	0.000	0.968	0.000	375
logGI	-0.233	2.987	0.992	0.034	0.993	0.066	375
logCIV	-1.196	3.819	0.904	0.000	0.908	0.000	375
logGOV	0.068	2.990	0.972	0.000	0.974	0.000	375

Table 6. Tests Of Normal Distribution

Note: *** denotes statistical significance at 0.01%

Source: Author's elaboration with SCIMAGOJR (2020) data, World Bank (2020), KOF (2021) and Freedom House (2021)

Similarly, Figure 3 illustrates the most widely used test for normal distribution: the Q-Q plot. This plot visualizes the probability distribution of the data, helping to determine if it adheres to a normal distribution. When the Q-Q plot aligns with the blue straight line in each panel (representing a variable), it suggests that the data is normally distributed. In contrast, any deviation from this line indicate a non-normal distribution. The results for each panel reveal that

the Q-Q plots for all variables deviate from the straight line, confirming that their distributions are not normal.

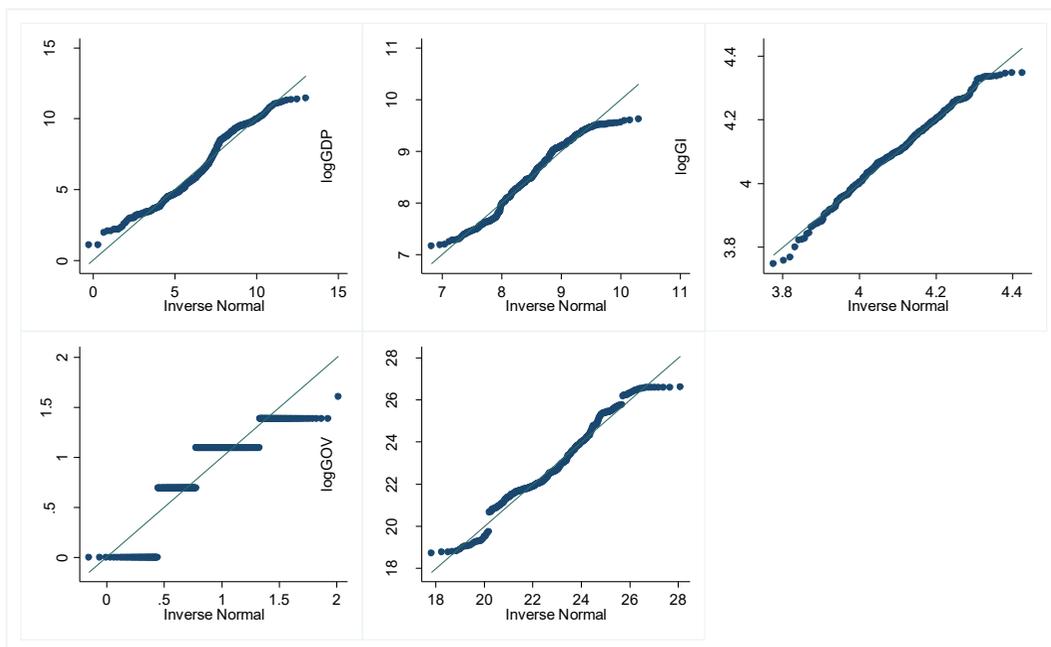


Fig. 2. Normality Graph of Variables

Source: Author’s elaboration with SCIMAGOJR (2020) data, World Bank (2020), KOF (2021) and Freedom House (2021)

Given the rejection of normality and the heterogeneity in the data, quantile regression proves particularly useful. Table 6 presents the quantile regression estimates across the conditional distribution. GDP per capita exerts a positive effect on scientific production at the lower and upper tails (10th, 20th, and 90th percentiles), but a negative influence at the 60th percentile. In contrast, globalization and government expenditure consistently exhibit positive and statistically significant effects across all quantiles (at the 1% level). Interestingly, civil liberties are associated with a significant reduction in the number of publications across all quantiles, also at the 1% level. These results highlight the heterogeneity in the estimated coefficients.

		Quantile regression								
	OLS	10th	20th	30th	40 th	50th	60th	70th	80th	90th
logGDP	0.20 5*	0.28 6*	0.19 6*	0.10 6	0.00 341	- 0.12 7	- 0.17 0*	- 0.09 75	0.12 6	0.55 7**
	(2.16)	(2.32)	(2.23)	(1.24)	(0.04)	(- 1.49)	(- 2.04)	(- 0.61)	(0.65)	(2.86)
logGI	2.28 4***	3.18 3***	3.33 7***	3.15 1***	3.08 5***	3.13 8***	3.08 6***	2.79 4***	2.17 4***	1.72 4***

	(6.32)	(7.84)	(12.6 7)	(7.59)	(5.85)	(5.76)	(4.82)	(4.95)	(5.09)	(4.00)
logCIV	- 0.46 8***	- 0.31 5***	- 0.29 9***	- 0.41 5***	- 0.51 3***	- 0.59 1***	- 0.62 9***	- 0.69 9***	- 0.58 6**	- 0.04 06
	(- 3.92)	(- 4.40)	(- 3.39)	(- 4.08)	(- 4.46)	(- 5.18)	(- 3.64)	(- 3.84)	(- 3.23)	(- 0.18)
logGOV	1.12 1***	1.26 8***	1.24 2***	1.22 7***	1.20 3***	1.19 6***	1.17 9***	1.12 7***	1.04 5***	1.01 1***
	(41.8 9)	(42.8 1)	(61.4 4)	(62.5 4)	(68.3 6)	(70.6 7)	(46.8 8)	(23.2 5)	(21.3 0)	(36.1 5)
Constan t	- 30.0 1***	- 38.5 5***	- 37.6 6***	- 35.5 6***	- 33.6 3***	- 32.3 5***	- 31.2 3***	- 29.2 0***	- 26.5 5***	- 27.7 7***
	(- 23.2 9)	(- 25.9 6)	(- 33.2 6)	(- 20.6 3)	(- 15.8 3)	(- 16.3 6)	(- 11.6 9)	(- 14.7 2)	(- 19.4 1)	(- 22.4 3)
Observa tions	375	375	375	375	375	375	375	375	375	375

Table 6. Quantile Regression Results

Note: *** denotes statistical significance at 0.01%

Source: Author's elaboration with SCIMAGOJR (2020) data, World Bank (2020), KOF (2021) and Freedom House (2021)

These finding highlight the importance of considering distributional heterogeneity. Unlike ordinary least squares (OLS), which estimates the average effect of independent variables, quantile regression reveals how these effects vary across the spectrum of scientific productivity. Figure 3 illustrates this distinction: the solid dark line represents the OLS estimate, while the quantile-specific estimates vary across the distribution. The shaded areas in each panel indicated confidence intervals, with wider intervals reflecting greater variability.

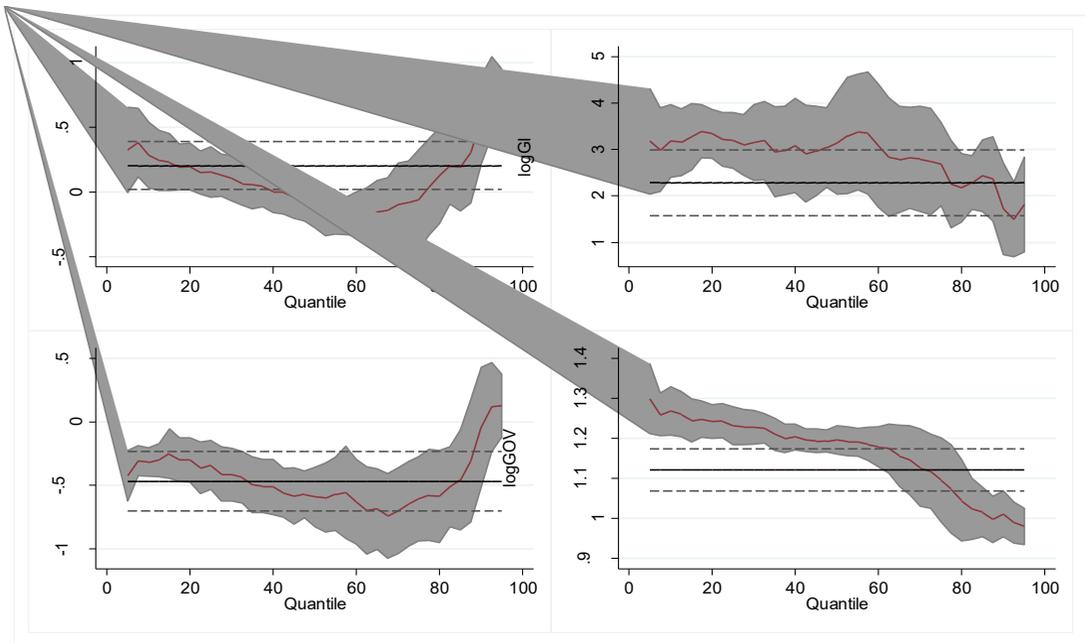


Fig. 3 Quantile Distribution of The Independent Variables Over the Publications Logarithm

Source: Author's elaboration with SCIMAGOJR (2020) data, World Bank (2020), KOF (2021) and Freedom House (2021)

Figure 3 depicts the quantile distribution of various independent variables in relation to the logarithm of publications. The x-axis represents quantiles ranging from 0 to 100, while the y-axis displays the logarithm of the number of publications. Each graph features a solid median line and a shaded area indicating variability or confidence intervals around the median. These visualizations reveal how the independent variables are distributed across different quantiles, with wider shaded areas signifying greater variability and narrower areas indicating more consistency.

Furthermore, the graphs highlight the increasing number of interregional collaborations in scientific articles, emphasizing the importance of cross-regional cooperation in driving innovation and boosting scientific output. This trend underscores the critical role of collaborative efforts in advancing research and knowledge dissemination.

Discussion

The findings of this study reveal several important relationships. Most notably, GDP per capita exhibits a positive and significant association with scientific output within the sample. This result aligns with the conclusions of Bueno-de-la-Fuente et al. (2019) and Chen and Wu (2019), who also reported strong positive correlations between economic performance and research productivity. In contrast, other studies such as those by Abramo and D'Angelo (2015) and Oyeyemi and Adeleke (2020) found differing results in European and African contexts, respectively. The quantile regression analysis in this study further indicates that the positive effect of GDP per capita is more prominent among higher-income countries – contrasting with some findings from Alshahrani et al. (2018), Rafols et al. (2021), and Lopez-Ornelas et al.

(2019), who emphasized the relevance of this relationship in both high- and middle- income nations.

As for the globalization index, a consistently positive and significant relationship with scientific production is observed across all quantiles. These findings are in line with those of Han et al. (2020), who documented similar effects across 41 Asian countries, and Hou et al. (2019), who reported a positive impact of globalization on scientific output in China. Chen et al. (2021) further reinforce this perspective, attributing the improved research capacity in developing countries to globalization's role in expanding access to essential technologies and resources. Nevertheless, not all studies concur – Abramo et al. (2017) and Singh and Kaur (2018) found no significant correlation in European and Indian contexts, respectively.

International scientific collaboration also emerges as a critical factor. As noted by Cai and Luo (2021), cross-border partnerships foster cooperation and strengthen scientific output. These dynamics support the observed positive correlation between civil liberties and the number of published scientific articles. Prior studies – including those by Akhmedjonov and Haynes (2019), Mashhood and Siddiqui (2021), Elveren and Duzgun (2020), and Abramo et al. (2017) – have shown that academic and press freedom play a pivotal role in enabling research productivity across both global and regional contexts. In the case of China, Lu et al. (2020) and Gao et al. (2021) reported that universities with greater academic freedom tend to produce more research output.

Public expenditure also appears to be positively and significantly associated with scientific production across all quantiles. This supports earlier findings from Ramorez-Aleson and Vicente Perez (2013) and Rassenfosse et al. (2013), who highlighted the beneficial role of government spending in enhancing research output in European contexts. However, the results of Abramo et al. (2019) suggest a more nuanced picture, as they found no significant correlation between public R&D investment and publication output, instead of highlighting the greater importance of educational quality and private sector investment in research.

Taken together, these results confirm the substantial influence of economic performance, globalization, civil liberties, and government expenditure on scientific production in Latin America. The findings emphasize the importance of these structural and institutional factors in shaping a supportive research environment, both at the national and regional levels.

Conclusions and Recommendations

The analysis reveals that GDP per capita is a crucial factor influencing the number of scientific articles published by a country. Countries with higher income levels have more financial resources to invest in R&D and scientific infrastructure, which leads to increased scientific knowledge production. Therefore, governments and business leaders should focus on improving the economy and increasing GDP per capita to drive scientific and technological development.

The globalization index also plays a vital role in influencing the number of scientific articles published. Globalization facilitates the exchange of knowledge and technology among countries, promoting scientific research worldwide. Governments and business leaders should encourage international cooperation to enhance scientific research and take full advantage of globalization's benefits.

Similarly, civil liberties are fundamental to fostering scientific research and technological development. Freedom of thought, expression, and access to information are essential for

researchers to explore and develop new ideas. Governments and institutions must guarantee and protect civil liberties to support global scientific and technological progress.

Public spending is another crucial factor influencing the number of scientific articles published by a country. Investment in R&D and education can lead to an increase in scientific output. Governments should increase their investments in R&D and education to promote scientific and technological progress.

Based on the literature review, it is evident that GDP per capita, globalization, civil liberties, and public spending significantly influence a country's scientific publication output. Therefore, to foster scientific knowledge, policies should be implemented that promote economic growth, support international trade, protect civil rights, and invest in research and development.

It is important for governments to invest in education and promote the creation of research centers in universities and other institutions. Incentives for researchers – such as grants and research subsidies – should be provided to enable high-quality research. Moreover, policies should foster collaboration among researchers from different countries, which can enhance research quality.

Institutional quality, encompassing governance effectiveness, regulatory quality, and the rule of law, is also crucial in determining a country's level of scientific output. Effective institutions create a stable environment for research by ensuring transparency in funding, protecting intellectual property rights, and encouraging collaboration between universities, industry, and government. Thus, countries aiming to increase their scientific production should prioritize improving institutional frameworks and governance standards.

Additionally, advancements in digital infrastructure – including widespread internet access, digital libraries, and online collaboration platforms – have a significant impact on scientific research and publication rates. Digital infrastructure facilitates the rapid dissemination of knowledge, enables international collaboration, and provides researchers with access to global data and resources. Consequently, governments and institutions should prioritize investments in digital infrastructure and technological connectivity to enhance scientific output. Countries with advanced digital systems are better positioned to engage with the global scientific community and make meaningful contributions to scientific knowledge.

Governments must also guarantee academic freedom and respect for human and civil rights. Freedom of expression and the protection of intellectual property rights are essential for the promotion of scientific knowledge. Furthermore, regulatory frameworks should protect researchers' interests and ensure transparency in the allocation of research funding.

In summary, implementing policies that promote economic growth, facilitate international trade, protect civil liberties, and support research and development is essential for advancing scientific knowledge production. These policies should be designed to foster international collaboration, protect intellectual property, establish appropriate regulatory frameworks, and ensure transparency in research funding allocation.

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