

Higher education efficiency analysis: Evidence from Latin America

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Abstract– *Efficiency in higher education is a key indicator, especially for public funded universities to secure the resources they need. This study analyses higher education inefficiency with a sample of 100 institutions of five Latin American countries. A two stage Simar and Wilson procedure is used to first obtain scores for research and academic inefficiency and in the second stage to assess the impact of several variables such as province GDP, budget and university age on both inefficiency scores. The results show that both research and academic inefficiency are negatively associated with budget and university age. However, province GDP is negatively associated to research inefficiency but positively related to academic inefficiency. Public policy should prioritize the development of internal institutional capacity through multi-year funding frameworks that are connected to improved efficiency in both research and teaching*

Keywords– *Efficiency analysis; Higher education; Universities; Simar–Wilson model; Academic.*

I. INTRODUCTION

Higher education, particularly in Latin America, is under increasing pressure to improve productivity and the quality of its offerings. As higher education institutions make major financial and human resource investments, efficiency analysis becomes an essential tool for ensuring that resources (inputs) are properly utilized, enhancing educational outputs while minimizing resource waste. Efficiency is more than just cost-effectiveness; it also involves aligning institutional performance with broader goals, such as enhancing the quantity and quality of publications, citations, and successful graduates [1]. Furthermore, comprehending the simultaneous problems of global competitiveness and regional restrictions confronting Latin American universities gives light on their academic and research efficiency [2]. In this perspective, examining public universities' academic and research efficiency using advanced approaches, such as semi-parametric models of production processes [3], provides a complete framework for assessing their contributions to societal progress.

To preserve and improve global competitiveness in a globalized society, higher education systems must work more effectively. Economies with high educational attainment are more likely to maximize their human and technology capital [4]. Furthermore, budget allocation and policy investment in public education are critical for developing a future workforce that will require more skilled professionals. As a result, spending on education not only invests in certification and professional development, but it also increases worker productivity, which contributes to national development [5;6].

Higher education in Latin America faces a complex mix of challenges and opportunities. Despite efforts to increase access, considerable discrepancies remain in terms of socioeconomic status, ethnicity, and gender organizations. Furthermore, educational quality varies greatly amongst institutions. In this setting, raising the quality of higher education is critical. Higher education's performance in meeting societal objectives is ultimately determined by the faculty skill, the rigor of academic programs, student participation, and the general quality of the learning environment [7].

Universities are a complex educational system shaped by both internal and external factors. Because of this, it is important to analyze the effect that these factors have on the efficiency of universities. Several approaches have been utilized to examine efficiency in higher education, including Data Envelopment Analysis (DEA), a nonparametric method used to measure the efficiency of decision-making units (DMUs) with many inputs and outputs [8;9;10;11;12;13]. DEA enables the establishment of an empirical production frontier, which represents the most productive units, and helps the evaluation of inefficiency based on the distance of observations from this frontier [14; 15]. In the context of Latin American public institutions, this method provides a strong instrument for evaluating resource efficiency, delivering insights into potential areas of improvement in both academic and operational dimensions [16].

According to the literature, ref [3] double DEA bootstrap technique is used to assess how efficiency changes as resource performance criteria are selected. This approach is implemented in a limited number of recent studies, which used this two-stage process to address efficiency evaluation in varied areas [17;18;19]. The authors emphasize that the standard two-stage strategy is not justified without a clear description of the underlying data-generation process. They further criticize the standard inference methods often employed in two-stage applications, claiming that they fail to account for the fact that DEA efficiency ratings are calculated using a shared dataset. In the context of assessing the efficiency of public universities in Latin America, this technique offers a more robust and reliable tool for comprehending efficiency changes and overcoming the constraints of existing methodologies.

On the other hand, a rising number of studies have investigated university operational processes and assessed their efficiency. However, most of these research focuses on a single country or private universities. In contrast, this research seeks to close this gap by estimating the efficiency of 100

public institutions in four Latin American nations and comparing their performance using university-specific metrics. When it does so, it adds to the current literature by conducting a broader, cross-national investigation of public university efficiency in an area that has gotten little attention in this regard.

The paper is structured as follows: Section 2 reviews the relevant literature; Section 3 explains the methodological approach and data; Section 4 presents the major findings, while Section 5 discusses the conclusions and policy implications derived from the key results.

II. LITERATURE REVIEW

Efficiency evaluations identify areas for improvement and optimization in the administration of financial, human, and technological resources in educational institutions. According to the literature, some countries have utilized different inputs and outputs to evaluate the efficiency of higher education. For instance, Ref [8] measured the operational efficiency of 52 Chinese colleges using data envelopment analysis (DEA) and a non-parametric approach. The authors analyse the efficiency in teaching and research using input indicators such as, full time teacher number, education, research funding and number of mater and Ph.D. students. Conversely, the number of undergraduate students, numbers of published papers, actual income of patents and numbers of awards, were used as outputs. The findings revealed that most of the universities assessed are still struggling with inadequate resource management and performance.

Ref. [10] assessed the effectiveness of 19 technological universities in Poland. The output-oriented and CCR-CRS DEA model was employed in the study. The relationship between the efficiency attained and the economies of scale was also examined. For the study, input variables (Government budget, number of academic teachers, numbers of employees and Phd student), outputs (Weighted number of full-time students, percentage of international students, percentage of students with scholarship and hiring alumni) and environmental variables (population size and percentage of students with financial aid) were applied. The findings demonstrated that because the weighted number of students and the evaluation of research achievements are arbitrarily selected, extreme caution should be exercised when interpreting the conclusions of university efficiency estimates.

Several studies have investigated the factors that influence university efficiency in specific countries. For instance, ref [9] estimated the efficiency of 120 Russian public higher education institutions for the 2012-2014 academic years. The authors applied a Tobit model to evaluate the effect of the variables and the data development analysis (DEA) as the HEI's efficiency metric. The findings indicate that there is still a need to improve efficiency. Furthermore, there is a

negative correlation with the gross regional product, but a positive correlation.

Ref. [13] examined the effectiveness of Higher Education Institutions (HEIs) in 31 Chinese provinces. In this investigation, a three-stage DEA was used. The authors also looked at the provinces' average level of higher education, their degree of openness, and their degree of economic development. The results indicate that as economies develop, educational institutions tend to operate with more resources than necessary, which generates inefficiencies. This could be an area for improvement to optimize the use of resources in countries with advanced economies. However, each input indicator has a negative relationship with the foreign invested (NFE) indicating that as the share of NFE increases, input decreases.

On the other hand, few studies have focused on Latin America countries. For instance, ref. [16] evaluated the efficiency and factors influencing public universities in Argentina. The authors applied a nonparametric DEA approach to determine efficiency ratings, followed by parametric modeling in the second stage to panel data from 2004 to 2013. The main results showed that variables connected to high-ranking professors have a favorable and significant outcome on efficiency levels. However, variables related to budget allocation have no meaningful influence. Finally, ref. [12] investigated the factors affecting efficiency in Brazilian Federal universities. The DEA was applied to a panel data of 59 universities from 2013 to 2017. The findings indicate that some universities were inefficient during this time. Furthermore, it was demonstrated that public funding, the number of professors, enrollment, graduates, and staff had a significant effect on efficiency.

Based on the above, there is still a gap in the literature about the evaluation of public higher education efficiency in Latin America. There are few studies in the region, and those that exist are limited to a single country and focus exclusively on academic efficiency. Therefore, the main contribution of this paper is to calculate the academic and research efficiency of 100 universities located in Ecuador, Colombia, Brazil, Argentina and Chile. For this purpose, a two stage DEA model is proposed with the ref. [3] approach by using truncated regression estimation with double bootstrap to test the significance of explanatory variables on the high education efficiency.

II. METHODOLOGY AND DATA

This study analyses higher education efficiency using a sample of 100 universities in four Latin American countries, applying a two stage DEA approach. In the first stage the efficiency value is calculated and in the second stage, a regression is conducted to analyse exogeneous factors which can affect universities efficiency.

A. Methodology

Ref. [3] approach is applied to address DEA traditional issues. This methodology provides a double bootstrap process that yields consistent inferences for factors influencing efficiency and a confidence interval for efficiency estimates. The authors also outlined the Data Generating Process (DGP) that underpins their two-stage approach.

In the first stage, DEA is used to calculate the efficiency of high education institutions. This methodology provides a non-parametric efficiency estimation for each decision-making unit (DMU), compared with the higher frontier. For this, we choose the variable return to scale (VRS) to calculate the efficiency, to allow the best input-output level according to the size of the sample.

Considering that $DMU_j; j = 1, 2, \dots, n$ transform an input vector $X_j = (x_{1j}, \dots, x_{bj}) \in R_+^b$ into an outputs vector $Y_j = (y_{1j}, \dots, y_{aj}) \in R_+^a$.

The DEA estimator is shown in the following equation:

$$\begin{aligned} \min \rho & \\ \text{s.t.} & \\ \sum_{j=1}^n \delta_j x_{ij} &\leq \rho x_{i0}, i = 1, \dots, b \\ \sum_{j=1}^n \delta_j y_{kj} &\geq y_{k0}, k = 1, \dots, a \\ \sum_{j=1}^n \delta_j &= 1 \end{aligned} \quad (1)$$

In equation (1) ρ is the value of efficiency of university j . In addition, δ_j indicates the weight of input and output vectors and $\sum_{j=1}^n \delta_j = 1$ imposes VRS assumption of the technology.

In the second stage, Ref. [3] proposed a truncated regression:

$$\hat{\rho}_j = \beta Z_j + \varepsilon_j, \quad j = 1, \dots, n \quad (2)$$

Where $\hat{\rho}_j$ is the efficiency estimated in the first stages, the explanatory variables vector is represented by $Z_j = 1, z_{1j}, \dots, z_{rj}$ and ε_j is the error. The DEA with bootstrap is represented by:

$$\tilde{\rho}_j \approx \beta Z_j + \varepsilon_j, \quad j = 1, \dots, n \quad (3)$$

Where $\tilde{\rho}_j = \hat{\rho}_j - \text{Bias}(\hat{\rho}_j)$ and $\varepsilon_j \rightarrow (0, \sigma_\varepsilon^2)$. This model is estimated to apply a maximum likelihood and the inference on coefficients is made on bootstrap approach.

B. Data description

This research is based on data from 100 Latin American universities in 2019. In the first stage, both input and output were chosen to determine two types of efficiency, academic and research efficiency. According to the literature, inputs are commonly used as proxy for labor and capital components. While the number of faculty is widely accepted and easy to compare, capital inputs are more difficult to standardize and generate debate. This could influence the results of the analyses, as the way these inputs are defined and measured affects the conclusions about the efficiency of the institutions [20;21]. While the outputs in university efficiency analysis are typically related to the outcomes of teaching and research activities, including indicators such as the number of graduates, research publications, and citations [22;23].

The data on institution characteristics were collected from SciVal, a research analysis platform that offers extensive tools for evaluating and benchmarking academic research performance, including indicators like publication volume, citation counts, and collaboration networks. Explanatory factors were acquired from official government platforms where the universities are located. These platforms supplied data on a variety of factors influencing university operations and performance, including government funding, educational regulations, and other area features. Table I shows input and output variables employed to calculate the research and teaching efficiency.

TABLE I
INPUT AND OUTPUT VARIABLES

Efficiency Type		Variables Description
Research	Input	• Ph.D. professors % (ProfPhd) • International collaboration % (IntColab) • Number of students (Nstudents)
	Output	• Scholarly Output (Schoutput) • Output in Top 10% Citation Percentiles (%) (Outputcit)
Educational	Input	• Number of professors (Nprofessors) • Number of degrees (Ndegrees)
	Output	• Number of graduate students (Ngraduated)

As mentioned above, this study assesses two categories of efficiency. The first category, research efficiency, is determined by the number of Ph.D. academics and the percentage of international collaboration at the university. The latter variable quantifies the percentage of scientific papers published by the university with at least one co-author from a foreign institution. In addition, this input indicates the university's ability to build collaborative research networks with worldwide universities, which improves the quality and impact of its research. In terms of output, the first variable is scholarly output, which refers to the total number of academic works produced by the university, such as journal articles, conference papers, book chapters, and scientific publications. Furthermore, the variable "Output in Top 10% Citation Percentiles (%)" is used to evaluate the quality of publications by calculating the proportion of a university's publications that are in the top 10% most referenced in their categories.

Moreover, the number of professors, students, and degrees awarded were used as an input to calculate academic efficiency. The outputs comprised the number of students who graduated throughout the study year, as well as scholarly production. Finally, in the second stage, we examine the factors of higher education institution efficiency using the method presented by ref. [3].

The variables employed in this stage are:

TABLE II
EXPLANATORY VARIABLES

<i>Exogenous Variables</i>	<i>Description</i>	<i>Unit</i>
Province GDP	GDP of the province to which the HEI belongs	US dollars
Budget	Annual executed budget amount	US dollars
University age	Years of HEI's existence	Years

Exogenous factors in this research include the GDP per capita of the region in which each institution is located, which serves as an essential indicator of regional economic conditions and is expected to have an impact on university efficiency. Universities in more affluent regions are predicted to show a positive relationship between GDP and efficiency. However, universities in less prosperous areas may play an important role in supporting regional development, resulting in an inverse association [24]. Furthermore, regional GDP per capita has a significant impact on finance, talent acquisition, collaboration, innovation, and social impact.

Another significant component to evaluate is the executed budget, which represents the primary resources provided by each organization, such as staff expenses, operational costs, and investments. The institution's executed budget has a direct impact on its ability to support research, improve teaching quality, create innovation, and efficiently manage its operations. A well-structured and properly managed budget

allows higher education institutions (HEIs) to run more efficiently [24;25].

The last factor is the institution's age, which corresponds to the year it was founded. Older institutions, with established traditions and reputations, are thought to be more efficient. By contrast, younger institutions have the potential to be more adaptable [26]. In contrast, institutions with a longer history have advantages such as more resources, prestige, and existing networks; yet these universities must balance tradition with innovation. Their ability to adapt to change and remain relevant in today's setting will be critical to preserving efficiency and profitability.

Analyzing the impact of these variables on university academic and research efficiency facilitates the identification of areas for improvement, the development of sound strategies, and the formulation of successful policies that promote academic excellence and organizational efficiency. The evaluation of these variables provides a more comprehensive and nuanced understanding of the factors that contribute to university success.

TABLE III
DESCRIPTIVE STATISTICS

Variables	Obs	Mean	Std.dev	Min	Max
ProfPhd	100	176.2359	366.0178	2	2369
IntColab	100	0.40347	0.521615	0.134	0.749
Outputcit	100	0.0622	0.0344378	0.001	0.169
Schoutput	100	1747.64	2955.38	16	16279
Nstudents	100	22355.89	35669.12	1406	318935
Nprofessors	100	1650.56	2632.307	228	22815
Ndegrees	100	80.08	54.6812	21	376
Ngraduated	100	2524.33	2585.243	111	17344
Budget	100	1.26e+08	2.07e+08	15231.13	1.30e+09
ProvGDP	100	1.30e+07	4.04e+07	6322.754	2.04e+08
Univ_age	100	61.07	57.90017	4	406

III. RESULTS

This section presents the results of technical efficiency estimation using the ref [3] methodology. This approach enables the generation of more accurate and unbiased estimates through a two-stage process: an initial estimation of technical efficiency followed by a correction using bootstrap techniques. The subsequent sections analyze the distributions of technical efficiency and examine potential causes of the observed variations. Furthermore, an interpretation of outliers is provided, along with the validation of the robustness of the applied models.

The findings of the universities' research and academic efficiency analyses are shown in Table IV. The bias-corrected inefficiency scores show that Latin American universities consistently operate below the efficient frontier in both

research and academic activities, albeit the extent of inefficiency varies by country and missions. Research inefficiency is more dispersed than academic inefficiency, indicating that institutions are more diverse in their ability to convert input into research output than into teaching outcomes. Institutions in Colombia and Ecuador tend to cluster closer to the frontier, with research inefficiency scores ranging from 1.05 to 1.20, while academic inefficiency is mild. Chilean universities display more varied patterns, with certain institutions exhibiting higher research inefficiency despite relatively restricted academic gaps. In contrast, Brazilian institutions routinely have greater research inefficiency levels, frequently reaching 1.25 and in some cases nearing or exceeding 1.35, indicating significant unfulfilled research potential given available resources.

Academic inefficiency has a more compressed distribution across countries, with most institutions functioning within a smaller range. While some Brazilian and Argentine universities attain minimal academic inefficiency, many institutions, particularly in Brazil, continue to have significant teaching gaps. Argentine universities follow a mixed pattern: some are placed near the frontier in both dimensions, while others exhibit moderate inefficiencies, particularly in research. Overall, the findings show a structural asymmetry among missions: teaching activities appear to be closer to best-practice norms than research, emphasizing ongoing issues in the organization, incentives, and size of scientific production in Latin American higher education systems.

TABLE IV
HEI'S INEFFICIENCY

HEI	Country	Research inefficiency	Academic inefficiency
Universidad de Antioquia	CO	1.146064	1
Universidad del Atlántico	CO	1.187074	1.124941
Universidad Colegio Mayor de Cundinamarca	CO	1	1.300546
Universidad Distrital Francisco José de Caldas	CO	1.097223	1.134864
Universidad Militar Nueva Granada	CO	1.150223	1.155728
Universidad Nacional Abierta y a Distancia	CO	1	1.082668
Universidad Nacional de Colombia	CO	1.110125	1
Universidad Pedagógica Nacional	CO	1.076528	1.207273
Universidad de Cartagena	CO	1.14151	1.136987
Universidad Pedagógica y Tecnológica de Colombia	CO	1.119213	1.094428
Universidad de Caldas	CO	1.194991	1.128277
Universidad del Cauca	CO	1.133166	1.079522
Universidad de Córdoba	CO	1.084657	1.18748
Universidad de la Guajira	CO	1.045295	1.19909
Universidad del Magdalena	CO	1.119012	1.147064
Universidad de los Llanos	CO	1.111223	1.239485
Universidad de Nariño	CO	1.120496	1.120137
Universidad de Pamplona	CO	1	1.141291
Universidad Francisco de Paula Santander	CO	1.065706	1.15652
Universidad del Quindío	CO	1.143036	1.187025
Universidad Tecnológica de Pereira	CO	1.207618	1.140915
Universidad de Sucre	CO	1.196759	1.276288
Universidad del Tolima	CO	1.124872	1.154918
Universidad del Valle	CO	1.156469	1.044209
Universidad de Cuenca	EC	1.092191	1.184986
Universidad del Azuay	EC	1.174925	1.18225
Universidad Nacional de Educación, Ecuador	EC	1	1.266567
Escuela Superior Politécnica de Chimborazo	EC	1.027662	1
Universidad Nacional de Chimborazo	EC	1.080898	1.117774
Universidad Técnica de Cotopaxi	EC	1	1.217282

Universidad Técnica de Machala	EC	1.035672	1.172634
Escuela Superior Politécnica del Litoral	EC	1.037498	1.185504
Universidad de Guayaquil	EC	1.140953	1.139851
Universidad Estatal de Milagro	EC	1	1.169329
Universidad Técnica del Norte	EC	1.114089	1.14807
Universidad Nacional de Loja	EC	1.115424	1.173217
Universidad Técnica de Babahoyo	EC	1.019545	1.251201
Universidad Técnica Estatal de Quevedo	EC	1	1.221561
Universidad Laica Eloy Alfaro de Manabí	EC	1	1.160962
Escuela Politécnica Nacional	EC	1.055757	1.184257
Universidad Central del Ecuador	EC	1	1.078853
Universidad de las Fuerzas Armadas ESPE	EC	1.017848	1.058488
Universidad Estatal Península de Santa Elena	EC	1	1.235591
Universidad Técnica de Ambato	EC	1.141278	1
Universidad de Antofagasta	CH	1	1.166595
Universidad de Tarapacá	CH	1.092074	1.166196
Universidad de Atacama	CH	1.039069	1.224402
Universidad del Bío-Bío	CH	1.159058	1.195389
Universidad de La Serena	CH	1.084302	1.129273
Universidad de la Frontera	CH	1.130937	1.142722
Universidad de Los Lagos	CH	1.149183	1.144361
Universidad de Magallanes	CH	1.017117	1.129378
Universidad de Talca	CH	1.140087	1.208269
Universidad de Chile	CH	1.053082	1.156874
Universidad de Santiago de Chile	CH	1.109478	1.150589
Universidad Tecnológica Metropolitana	CH	1.178828	1.171044
Universidad Metropolitana de Ciencias de la Educación	CH	1.357791	1.139884
Universidad Arturo Prat	CH	1.412711	1.284441
Universidad de Valparaíso	CH	1.075771	1.153152
Universidad de Playa Ancha de Ciencias de la Educación	CH	1.27258	1.180094
Universidade Federal de Alagoas	BR	1.217817	1.115076
Universidade Federal do Amapá	BR	1.312038	1.162667
Universidade Federal do Oeste da Bahia	BR	1.454617	1.213726
Universidade Federal do Ceará	BR	1.18382	1.098455
Universidade Federal do Sul da Bahia	BR	1.486423	1.25609
Universidade Federal de Goiás	BR	1.231735	1.041714
Universidade Federal de Itajubá	BR	1.376309	1.235801
Universidade Federal do Cariri	BR	1.35161	1.345726
Universidade Federal de Minas Gerais	BR	1.223827	1.120738
Universidade Federal de Viçosa	BR	1.295262	1.166923
Universidade Federal de Lavras	BR	1.334224	1.209664
Universidade Federal de Ouro Preto	BR	1.214312	1.187828
Universidade Federal de São João del-Rei	BR	1.332351	1.180021
Universidade Federal dos Vales do Jequitinhonha e Mucuri	BR	1.242459	1.202408
Universidade Federal de Alfenas	BR	1.393614	1.255573
Universidade Federal do Pará	BR	1.207651	1.089967
Universidade Federal Rural da Amazônia	BR	1.296395	1.2334
Universidade Federal do Sul e Sudeste do Pará	BR	1.304613	1.241763
Universidade Federal de Campina Grande	BR	1.212965	1.153842
Universidade Federal do Paraná	BR	1.187526	1.082696
Universidade Federal de Pernambuco	BR	1.184118	1.110779
Universidade Federal do Piauí	BR	1.218468	1.110605
Universidade Federal Fluminense	BR	1.153703	1.081589
Universidade Federal Rural do Rio de Janeiro	BR	1.241662	1.135917
Universidade Federal do Rio Grande do Norte	BR	1.223326	1.116037
Universidade Federal Rural do Semi-Árido	BR	1.315276	1.198368
Universidade Federal de Santa Maria	BR	1.275922	1.099851
Universidade Federal de Pelotas	BR	1.301738	1.132586
Universidade Federal de Roraima	BR	1.246872	1.123527
Universidade Federal de Santa Catarina	BR	1.234387	1.099314
Universidade Federal de São Carlos	BR	1.343953	1.189403
Universidad de buenos aires	AR	1	1
Universidad Tecnológica Nacional	AR	1	1
Universidad Nacional de Luján	AR	1.127476	1.080633
Universidad Nacional Arturo Jauretche	AR	1	1.046237
Universidad Nacional de Lanús	AR	1.045713	1.266404
Universidad Nacional de Quilmes	AR	1.138874	1.044889
Universidad Nacional de Córdoba (UNC)	AR	1	1.018997
Universidad Nacional de Río Cuarto (UNRC)	AR	1.198827	1.057939
Universidad Nacional de la Patagonia San Juan Bosco	AR	1.120602	1.020648

A. Research efficiency

In addition to evaluating technical efficiency and using bootstrap bias correction, ref. [3] methodology allows for the assessment of external variables, offering a more thorough comprehension of the variables influencing technical efficiency.

It is crucial to emphasize that this model assesses how outside factors affect inefficiency. To determine the initial technical efficiencies, a stochastic frontier model is estimated in the first step of the analysis. Then the bootstrap technique is used to address any potential biases in the estimates. To obtain a more precise distribution of the estimated values, this procedure entails creating several bootstrap samples and recalculating efficiencies. To analyze the effects of the explanatory variables on the adjusted technical efficiencies, a regression of the bias-corrected technical efficiencies on the variables is finally carried out.

TABLE V
ESTIMATED MEAN MARGINAL EFFECT OF RESEARCH INEFFICIENCIES

Variable	Simar & Wilson Algoritm 2
Budget	-0.0167557 0.0000
ProvGDP	-0.00966384 0.0008
Univ_age	-0.0392839 0.0000

The marginal coefficients derived from the three estimated regressions are shown in Table V. The estimated mean marginal effects show that major institutional and contextual factors considerably reduce research inefficiency in Latin American universities. The institutional budget has a consistently negative and statistically significant effect across all parameters, with an estimated marginal effect of around -0.017 using the bias-corrected algorithm two. This sample shows that higher university financing relates to economically significant decreases in research inefficiency, highlighting the importance of solid financial resources in supporting scientific activity.

Regional economic considerations are also significant, though to a smaller degree. Provincial GDP has a negative and statistically significant effect (marginal effect = -0.0097), indicating that institutions in developed regions operate closer to the research efficiency frontier. University age emerges as a particularly powerful factor, with the highest marginal influence in absolute value, the predicted effect is around -0.039, demonstrating that institutional maturity significantly reduces research inefficiencies. This finding emphasizes the value of cumulative expertise, long-term investments in research capacity, and the establishment of academic norms and networks. Taken together, these data imply that, while financial resources are the key driver of increased research efficiency, institutional age and regional development provide

complementing benefits that shape institutions' ability to convert input into scientific output.

TABLE VI
SIMAR AND WILSON RESEARCH INEFFICIENCY (ALGORITHM 2)

Inefficiency	Obs .Coef	Bootstrap Std. Err.	Z	P > z
Tebc_vrs_o				
Budget	-0.0182748	0.0039119	-4.67	0.000
ProvGDP	-0.01054	0.0031958	-3.30	0.001
Univ_age	-0.0428454	0.010522	-4.07	0.000
_cons	1.826735	0.0778619	23.46	0.000
Sigma	0.0852702	0.0067105	12.71	0.000

The bias-corrected ref. [3] estimates (table VI) reveal that research inefficiency in Latin American universities is systematically associated with both institutional and environmental factors. Higher funding levels might help universities shrink the gap with the efficient frontier, as seen by a negative and substantial relationship between institutional budget and research inefficiency (coefficient = -0.018). This finding underscores the critical role that financial resources play in maintaining regional productivity.

Regional economic factors are also important. Universities in developed locations may perform research more effectively, as evidenced by a negative and statistically significant coefficient of approximately -0.011. In Latin American higher education systems, accumulated expertise, established research traditions, and mature academic networks play a significant role in reducing research inefficiency (coefficient = -0.043).

B. Academy efficiency

This assessment section, like the previous one, will analyze the academic achievement of the universities. The ability of educational institutions to efficiently employ the resources at their disposal to instruct students is referred upon as academic efficiency. This analysis examines a variety of internal and external factors within universities that may influence their academic efficiency.

TABLE VII
ESTIMATED MEAN MARGINAL EFFECT OF ACADEMY INEFFICIENCIES

Variable	Algoritm 2
Budget	-0.0081524 0.0249
ProvGDP	0.01204577 0.0000
Univ_age	-0.04649253 0.0000

Table VII displays the marginal effects of academic inefficiency across the three regressions utilized in the model. The data show a trend that differs from previous research

findings. The bias-corrected algorithm two shows a negative correlation between institutional budget and academic inefficiency, with a marginal effect of roughly -0.008. This suggests that increased financing can lead to modest but significant improvements in teaching performance. This effect is statistically significant and stronger than in the alternative estimators, indicating that internal financial resources play an important role in closing academic inequalities.

School age has a significant negative impact, with an estimated marginal effect of approximately -0.046 under algorithm 2. This emphasizes the value of institutional expertise, consistent academic routines, and long-standing teaching techniques in increasing academic efficiency. Provincial GDP, on the other hand, has a modest and positive correlation that is not statistically significant, demonstrating that regional economic conditions do not systematically influence academic inefficiency when institutional factors are considered. Overall, academic inefficiency appears to be influenced more by internal institution issues than by the external economic environment.

TABLE VIII
SIMAR AND WILSON ACADEMIC INEFFICIENCY (ALGORITHM 2)

Inefficiency	Obs.Coef	Bootstrap Std. Err.	Z	P > z
Tebe_vrs_o				
Budget	-0.0085415	0.0038292	-2.23	0.026
ProvGDP	0.0126207	0.0030451	4.14	0.000
Univ_age	-0.0487114	0.0101844	-4.78	0.000
cons	1.40848	0.0742156	18.98	0.000
Sigma	0.082864	0.0062673	13.22	0.000

The regression model (table VIII) results suggest that the external factors under consideration have a significant impact on the academic inefficiency of the public universities under investigation. Better-funded institutions can minimize inefficiencies in instructional activities, as evidenced by a significant negative correlation between institutional budget and academic inefficiency (estimated coefficient = -0.009). Although the amount of this effect is smaller than that observed in studies, it is still economically and statistically significant [27].

The coefficient of -0.049 indicates that older college's function closer to the academic efficiency frontier. This result demonstrates the role of accumulated expertise, robust academic systems, and established teaching approaches [28]. In contrast, provincial GDP demonstrates a positive and statistically significant coefficient of approximately 0.013, implying that once institutional resources and experience are controlled for, regional economic conditions do not necessarily translate into better academic efficiency, and may even be associated with higher academic inefficiency [29;30]. Overall, the results suggest that improvements in teaching efficiency in Latin America depend more on internal institutional development than on external economic context.

IV. CONCLUSIONS

This paper analyses the academic and research efficiency in public universities in five Latin America countries. To address the shortcomings of classic DEA, ref. [3] devised a two-stage method based on a double bootstrap was applied. This novel method has various benefits, including consistent inference for factors influencing efficiency and the ability to create confidence intervals for efficiency estimations.

The empirical results show that universities in Latin America operate systematically below the efficient frontier, with research inefficiency exhibiting greater dispersion than academic inefficiency. Teaching activities tend to be closer to best-practice standards, whereas research performance varies widely across institutions and countries. The data reveals strong cross-country tendencies, with universities in Colombia and Ecuador being closer to the border, whereas schools in Brazil and Argentina have bigger research disparities despite relatively little academic inefficiencies. These findings highlight systemic variations in research capacity and structure among the region's higher education systems.

Institutional characteristics play an important role in explaining inefficiencies. Higher institutional budgets are consistently associated with lower levels of research and academic inefficiency, highlighting the significance of proper and constant support. School age is also a powerful predictor, showing that accumulated expertise, established academic procedures, and consolidated research cultures improve universities' ability to convert input into output. Provincial economic conditions, on the other hand, have a limited and asymmetrical impact: while regional growth helps to reduce research inefficiency, it does not consistently increase academic efficiency once institutional considerations are accounted for.

These findings have significant policy implications for higher education in Latin America. Public policy should prioritize the development of internal institutional capacity through multi-year funding frameworks that are connected to improved efficiency in both research and teaching. Targeted support for emerging institutions is crucial for stimulating the growth of research infrastructure, academic governance, and human capital. Furthermore, governments should differentiate between missions, promoting long-term investments and collaborative networks in research while strengthening pedagogical quality and institutional stability in education. Adopting accessible, data-driven evaluation systems at the national and regional levels will boost accountability and lead to more efficient public resource allocation, ultimately improving universities' contributions to regional economic and social development.

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