Journal of Posthumanism
2025
Volume: 5, No: 4, pp. 71–90
ISSN: 2634-3576 (Print) | ISSN 2634-3584 (Online)
posthumanism.co.uk

DOI: https://doi.org/10.63332/joph.v5i4.990

Macroeconomic Determinants of the Economic Complexity Index in Ecuador

Aracelly Núñez-Naranjo[1], Mery Esperanza Ruiz-Guajala[2], Jeremy Moreno-Ortiz[3]

Abstract

This study seeks to identify the key variables that influence the variation and development of the Economic Complexity Index (ECI) in Ecuador, taking into account its impact on growth and competitiveness. It began with an exploratory data analysis (EDA) using line diagrams to examine the evolution and behavior of the variables over time, facilitating the identification of patterns and trends, subsequently, the Pearson correlation method is used to measure the strength and direction of the relationship between the ECI and key macroeconomic variables, thus identifying significant associations, in addition, multiple linear regression is applied to estimate the joint impact of these variables on the index, allowing determining the impact as well as the relative influence of these on the productive diversification and economic sophistication of Ecuador.

Keywords: *Complexity, Human capital, Development, Diversification.*

Introduction

A country's economic development depends to a large extent on its capacity to generate productive knowledge and transform it into sophisticated goods and services for subsequent commercialization. In this context, economic complexity has become relevant as a key approach to understand the differences in growth and competitiveness between nations. This concept, introduced by [1] and [2] is based on the idea that development depends not only on the accumulation of capital and labor, but also on the diversity and sophistication of the products that an economy can generate; in this sense, recent studies have shown that economies with higher levels of complexity tend to experience faster and more sustainable growth [3].

According to [4] productive diversification not only boosts competitiveness, but also reduces vulnerability to external shocks and improves the nation's macroeconomic stability, in particular, a country's ability to generate high value-added goods is closely linked to investment in innovation, education and technological development [5], therefore, economic development in Ecuador requires a comprehensive approach based on productive diversification and innovation, to analyze this process, three key theories were considered, first, the theory of economic complexity [1] [6] which argues that the productive knowledge accumulated in an economy is reflected in the diversification and sophistication of its goods and services, a higher level of economic complexity is associated with a more dynamic and resilient economic growth in the face of external shocks. From the perspective of endogenous technological change, [7] argues

[1] Centro de Investigación en Ciencias Humanas y de la Educación-CICHE, Facultad de Ciencias de la Educación; Universidad Tecnológica Indoamérica, Ambato 180103, Ecuador, Email: fernandanunez@uti.edu.ec.
[2] Facultad de Contabilidad y Auditoría, Universidad Técnica de Ambato, Ecuador
[3] Facultad de Contabilidad y Auditoría, Universidad Técnica de Ambato, Ecuador.

that innovation in technology and knowledge, as well as the accumulation of human capital, are key drivers of economic development; investment in research and development allows economies to generate competitive advantages and adapt to a changing global environment; likewise, the "creative destruction" proposed by [8] highlights the importance of technological renewal and productive specialization as mechanisms of economic modernization.

On the other hand, the human capital theory [2], [9] stresses the relevance of education and training in the generation of knowledge and productivity, a highly skilled workforce facilitates the adoption of advanced technologies and promotes productive diversification, in this context, digitalization and globalization have intensified the need to develop specialized skills that allow countries to insert themselves into value chains of greater complexity [10]. The economic complexity approach has been applied in various contexts to analyze the determinants of growth, for example, in Africa it has been found that the relationship between knowledge and development varies according to the level of income and institutional quality [11], while in Asia-Pacific, industrial modernization has been a key factor in improving competitiveness, with evidence that the production and export of sophisticated goods have boosted economic development [12].

Human capital is a key determinant of economic development, and strengthening it through education and technology policies has been shown to improve the absorptive capacity of new technologies and increase global competitiveness [13]. In regions such as the Persian Gulf and China, investment in education and training has contributed significantly to regional economic convergence, reducing development gaps and improving the quality of employment [14], [15], similarly, the relationship between economic growth and environmental sustainability has been the subject of debate, while authors such as [16] suggest that a higher level of economic complexity can reduce environmental degradation through the incorporation of clean technologies, others warn about the risks of a development based on the intensive exploitation of natural resources [17], in this sense, technological development and investment in human capital play a central role in the transition to more sustainable productive models [18].

According to [19], a country's competitive advantage lies in its capacity to develop innovative and differentiated productive sectors, which determines its insertion in global trade; this advantage depends not only on natural resources or production costs, but also on the sophistication of the knowledge incorporated in the exported goods, which in turn influences economic complexity; in this context, international trade and integration in global value chains have been identified as determining factors of economic growth. Studies have found a bidirectional relationship between the trade balance and macroeconomic stability, which suggests that access to international markets is key to productive diversification [20]. In this regard, [21] mention that foreign direct investment (FDI) has mixed effects: while in advanced economies it has contributed to an increase in economic complexity, in low-income countries its impact has been less uniform, and has even generated inequalities and environmental problems in some cases.

This study arises from the need to analyze how various factors influence the economic complexity of Ecuador, given its key role in growth and development, the results would contribute to policy makers to design strategies that promote productive diversification and reduce dependence on primary exports, strengthening economic resilience, likewise, this knowledge contributes to academia by strengthening the study of economic complexity in developing economies and their relationship with innovation, education and investment.

Background

Economic Complexity Index

Developed by [1] , the Economic Complexity Index (ECI) is a quantitative measure that evaluates the productive sophistication of a country based on the diversity and uniqueness of its exports. The ECI is based on the idea that economic development depends on the accumulation of productive capacities implicit in a country's export structure. Economic complexity not only fosters growth, but also contributes to the reduction of inequality, through appropriate policies affecting education, public spending and trade openness, which facilitates a decrease in income inequality[22].

According to [23], the ECI is a key determinant of economic growth, as it reflects the level of productive knowledge incorporated in the economic structure of a country, countries with more complex economies tend to diversify their production, which allows them to innovate and generate higher value-added goods, unlike economies dependent on natural resources, which can achieve high incomes without being complex, but are more vulnerable to external fluctuations, so that this index not only measures the level of productive sophistication, but also explains and anticipates the dynamics of economic development.

Foreign Direct Investment

Foreign direct investment (FDI) is characterized as a long-term investment in which an investor acquires a significant stake in a foreign company to influence or control its management, being a key driver of economic growth in host countries, generating positive externalities [24]. According to [25] FDI drives economic development by introducing advanced technology and capital, strengthening production, financing essential projects, generating employment and increasing local competitiveness, while facilitating export access to international networks.

Foreign capital plays a crucial role in promoting innovation, improving technological infrastructure and fostering the transfer of knowledge and skills [26]. According to [21] FDI has a negative impact on sustainable development in low-income countries, contributing to environmental degradation and increasing inequality, while in high-income countries it has a positive effect, highlighting the need to attract high-quality or “green” investments to maximize their benefits and mitigate adverse effects.

Trade Balance

The trade balance is an economic indicator that reflects the relationship of exchange of goods and services between a country and others, recording exports and imports during a given period, a surplus indicates that exports exceed imports, which can contribute to the country's economic growth, this indicator is crucial to assess the development and competitiveness of an economy [27]

The trade balance influences GDP growth, since a surplus indicates a solid productive capacity to compete in the international market, while a prolonged deficit can affect employment and national production. In Ecuador, many economic agents have directed their resources towards

importing goods and services, driven by factors such as quality and prices, which has generated a trade deficit with possible negative effects on the economy [28].

Capital Humano

Human capital is a determining factor in economic development, as it encompasses both education and the health of the population, essential aspects for increasing productivity and the capacity for innovation in an economy. Education, by providing individuals with skills and knowledge, improves employability and fosters creativity, key elements for technological transformation and global competitiveness, and also contributes to poverty reduction and social equity by generating opportunities for economic mobility and improving quality of life [29].

On the other hand, investment in health directly influences the development of human capital by improving the living conditions and productive capacity of the population. According to [30], health spending has a significant impact on GDP growth, given that it enables the formation of a healthier and more productive workforce, greater investment in health is associated with increased life expectancy and reduced economic losses from occupational health problems. Health spending can enhance economic complexity by improving quality of life and productivity, although its impact depends on structural and policy factors, and in high-income contexts it does not always translate into higher levels of economic sophistication [31].

Metodology

Population

In this study, the population is composed of macroeconomic data on foreign trade, foreign capital, human capital and economic performance of Ecuador between 2007 and 2021, allowing a comprehensive view of its economic and social structure..

The study used all available observations on Ecuador's macroeconomic variables, including the economic complexity index (ECI), foreign direct investment (FDI), the trade balance at current prices, the total number of graduate students in third level and current spending on health, ensuring a comprehensive analysis of the country's economic complexity.

Descriptive Analysis

To understand the dynamics of the variables over time, a descriptive analysis was performed using line graphs. This approach makes it possible to visualize trends and patterns in the evolution of the macroeconomic variables included in the study, facilitating the identification of possible relationships or structural changes in the period of analysis [32]. Graphical analysis complements the statistical methods used in the study by providing a visual representation of the variability of the data.

Correlational Analysis

Pearson's rank correlation coefficient

Next, the Pearson correlation coefficient is calculated, which measures the linear relationship between two numerical variables through the standardized covariance, allowing us to analyze how they vary together without establishing causality and providing a mathematical basis for evaluating their association by modeling relationships and supporting the hypothesis on the dependence between variables. As shown in Figure 1.

r-value	Interpretation
0.50 a 1	Strong positive correlation
0.30 a 0.49	Moderate positive correlation
0.10 a 0.29	Weak positive correlation
0 a 0.09	Null positive correlation
0 a -0.09	Negative null correlation
-0.10 a -0.29	Weak negative correlation
-0.30 a -0.49	Moderate negative correlation
-0.50 a -1	Strong negative correlation

Table 1 Pearson Correlation Coefficients

Note. Interpretation of Pearson's correlation coefficient. Source: Hernandez et al. (2018).

Pearson's correlation formula

$r = \frac{\sum(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum((X_i-\bar{X})^2}\cdot\sqrt{\sum((Y_i-\bar{Y})^2}}$ Hernández et al. (2018)

- X_i, Y_i = Individual values of variables X and Y.
- $\bar{X}, \bar{Y}$ = Means of the variables X and Y.
- $\sum(X_i - \bar{X})(Y_i - \bar{Y})$ = Covariance between X and Y.
- $\sqrt{\sum((X_i - \bar{X})^2}$ y $\sqrt{\sum((Y_i - \bar{Y})^2}$ = Standard deviations of X and Y, respectively.

Explanatory Analysis

Ordinary least squares (OLS).

The study used an ordinary least squares model to analyze the relationship between the economic complexity index and various macroeconomic variables. This approach allows evaluating the simultaneous effect of multiple explanatory factors on the dependent variable, providing a better estimate of the impact of each one of them; in addition, the model decomposes the variance of the dependent variable and measures the relative contribution of each predictor, which facilitates the economic interpretation of the model [33]. To ensure the validity of the model, tests were carried out to verify the fulfillment of its fundamental assumptions, necessary to ensure the correct obtaining of the results.

The general equation of the multiple regression is expressed as.

$Y=\beta0+\beta1X1+\beta2X2+...+\beta nXn+\varepsilon$

- Y (dependent variable): It is the variable we want to explain or predict.
- X1, X2, Xn (independent or explanatory variables): They are the factors that influence Y.
- β0 (intercept): It is the value of Y when all Xi are zero.
- β1, β2…, βn (regression coefficients): They represent the expected change in Y when the variable Xi increases by one unit, keeping the other variables constant.

- ε (término de error): (error term): Captures the variability not explained by X, i.e. factors not included in the model.

To validate the model, the coefficient of determination $R2$, which measures the variability explained by the independent variables, and statistical tests such as the t-test, which evaluates the individual significance of each regressor, and the F-test, which analyzes the joint significance of the model, were analyzed. These checks ensure the reliability of the results for the interpretation of the Economic Complexity Index (ECI).

Results

Line Diagram

Figure 1 shows the evolution of the economic complexity index in Ecuador during the period 2007-2021, evidencing a downward trend with fluctuations that reflect changes in the country's productive structure. Thus, in the early years, the ECI shows relative stability, followed by a peak in 2012, from which a sustained decline is observed until 2020, suggesting a progressive loss of productive sophistication and a possible greater dependence on lower value-added sectors [1]. This decline may be linked to macroeconomic and structural factors, such as reduced investment in strategic sectors, changes in economic policy or fluctuations in foreign direct investment [34].

The slight recovery observed in 2021 could respond to the post-pandemic economic reactivation and initiatives aimed at strengthening competitiveness in more knowledge-intensive sectors [35]. In this sense, the evolution of the ECI is a key indicator for evaluating Ecuador's capacity to integrate into global value chains and develop more technologically complex sectors, with direct implications for its long-term economic growth [36]

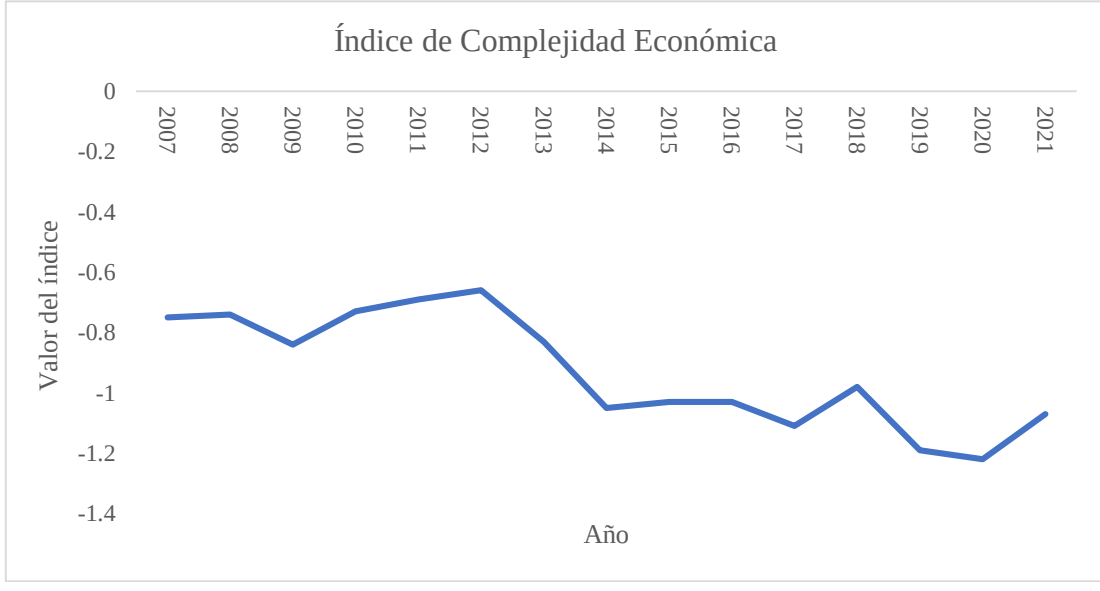

Figure 1 Line chart of Ecuador's ECI (2007 - 2021)

Note: Line graph of the economic complexity index. Source: (Harvard Growth Lab, 2024).

Figure 2 presents the evolution of foreign direct investment in Ecuador during the period 2007-2021, evidencing high volatility with significant fluctuations over time. A strong increase is observed in the period 2007 - 2008, followed by a sharp drop in subsequent years, which could be linked to the global financial crisis and its impact on capital flows to emerging economies [37], from 2011, FDI experiences moderate growth, reaching peaks in 2015 and 2018, which could be related to investment attraction policies and the relative stability of international markets in those periods [38], however, the drop after 2019 suggests possible adverse effects derived from the COVID-19 pandemic and the global economic uncertainty experienced during that crisis period.

These movements reflect the sensitivity of FDI to external factors and the country's capacity to generate favorable conditions for investment. According to [4], foreign investment not only responds to fiscal incentives and macroeconomic stability, but also to the presence of infrastructure and technological capabilities that favor productivity.

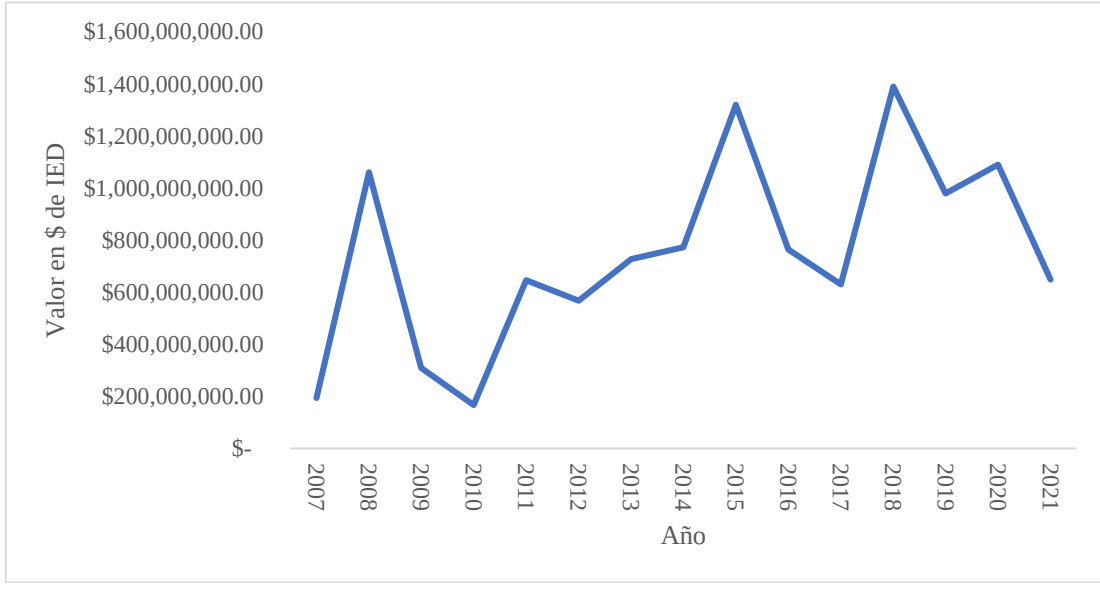

Figure 2 Line Chart of Foreign Direct Investment in Ecuador (2007 - 2021)

Note. line graph of FDI in Ecuador. Source: The World Bank (2023).

Figure 3 shows the evolution of health spending as a percentage of GDP in the period 2007-2021, which exhibits a growing trend, with a sustained increase from approximately 5.5 % in 2007 to values close to 9 % in 2021. This dynamic suggests a progressive strengthening of investment in the health sector, which could be associated with public spending expansion policies, improvements in health infrastructure or the impact of recent health crises, such as the COVID-19 pandemic from 2020 [39], likewise, the relative stability between 2015 and 2018 could indicate a period of budgetary consolidation or changes in resource allocation priorities, these results reflect the importance of sustained financing to ensure access to health services and its possible relationship with the country's economic development [40].

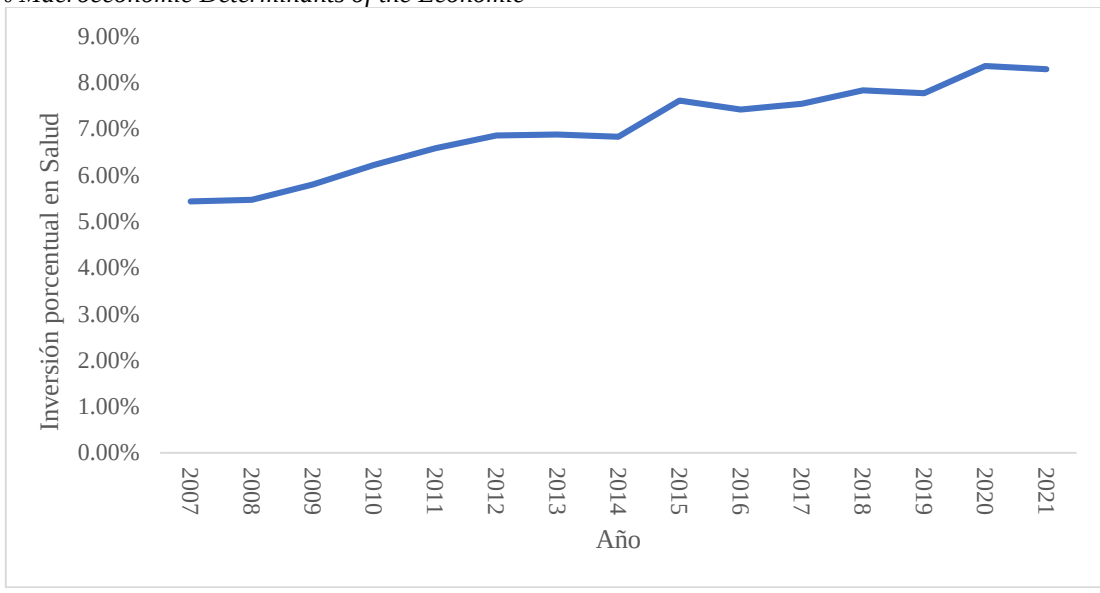

Figure 3 Line Chart of Health Spending in Ecuador (2007 - 2021)

Note. Line graph of health spending as a percentage of GDP in Ecuador. Source: The World Bank (2023).

Figure 4 shows the evolution of the trade balance in dollars for the period 2007-2021, evidencing a high volatility over time, such that a surplus is observed in the first years, followed by a decreasing trend that reaches its lowest point in 2015, which could be associated with external shocks, such as the fall in oil prices or trade restrictions [41], subsequently, the trade balance experiences fluctuations with periods of recovery and deficit, suggesting a dynamic relationship between exports, imports and the country's productive structure. According to the theory of Economic Complexity, a more diversified and sophisticated export system tends to generate a more stable and resilient trade balance, which has a bidirectional causal relationship with economic growth [1], [20], in this sense, the observed instability could reflect the dependence on sectors with lower value added, which reinforces the importance of promoting productive diversification to improve the country's trade position and the Economic Complexity Index (ECI).

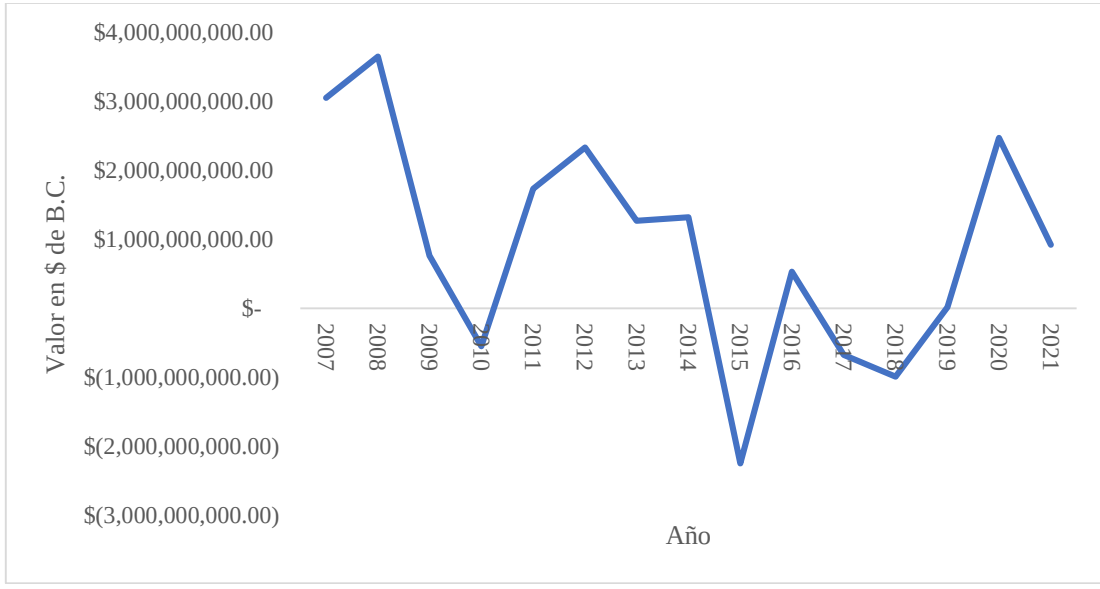

Figure 4 Line Chart of Ecuador's Trade Balance (2007 - 2021)

Note: Line graph of Ecuador's trade balance. Source: The World Bank (2023).

Figure 5 shows the evolution of the total number of students graduating at the tertiary level between 2007 and 2021, which shows a steady growth until about 2017, followed by a slight decline in subsequent years, with a steeper drop in 2019 and a slight partial recovery in 2020-2021. According to [9] human capital theory, higher education is a key determinant of economic development, as it improves the productivity and innovative capacity of the labor force, thus, in the context of economic complexity, a higher number of graduates can contribute to the productive sophistication of the country, facilitating export diversification and the improvement of the ECI [42], the drop observed in 2019 could be related to economic factors or changes in educational policies, while the partial recovery in 2020-2021 suggests a response to the need for human capital in a context of economic transformation [2], [43] this reinforces the importance of investment in higher education as a key mechanism for economic growth and improvement of the country's competitiveness.

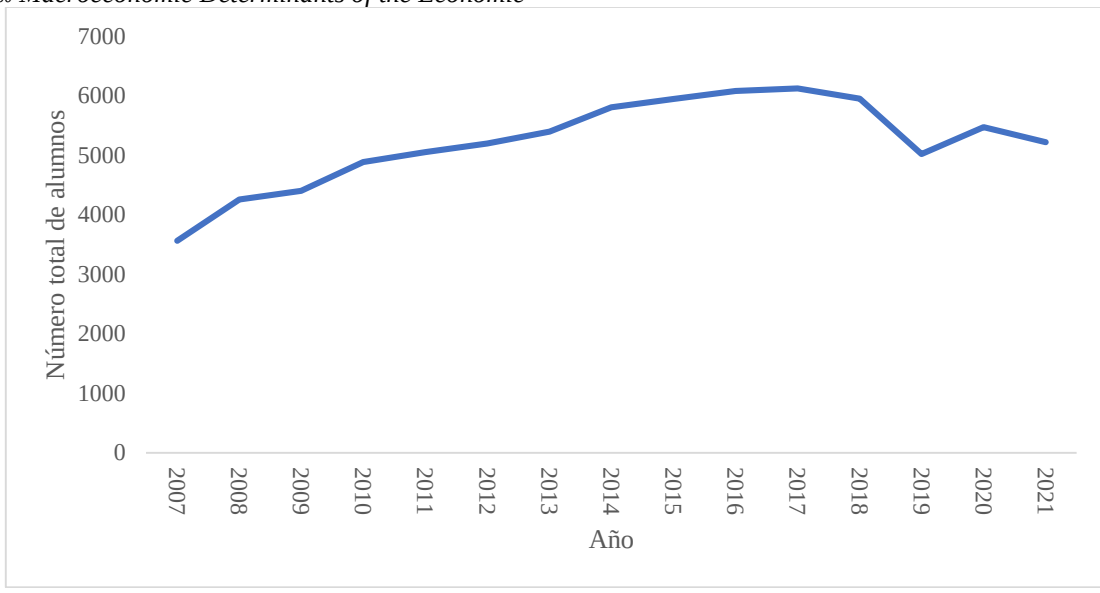

Figure 5 Line Graph of the Total Number of Students Graduating From Higher Education In Ecuador (2007 - 2021).

Note. Line graph of total students graduating at higher level Ecuador. Source: The World Bank (2023).

Figure 6 represents the evolution of education spending in Ecuador between 2007 and 2021, reflecting a sustained growth until 2019, followed by a reduction in 2020 and a slight recovery in 2021. This behavior can be analyzed from [9] human capital theory, which emphasizes investment in education as a key determinant of economic growth and productivity, and from [7] endogenous technological change perspective, higher spending on education could favor the accumulation of knowledge and innovation, essential elements to improve a country's economic complexity, In this sense, the decrease in spending in 2020 could have been a consequence of fiscal restrictions derived from the global health crisis, potentially affecting Ecuador's capacity to increase its economic complexity. These findings demonstrate the importance of maintaining sustainable investment policies in education to foster the country's economic and technological development.

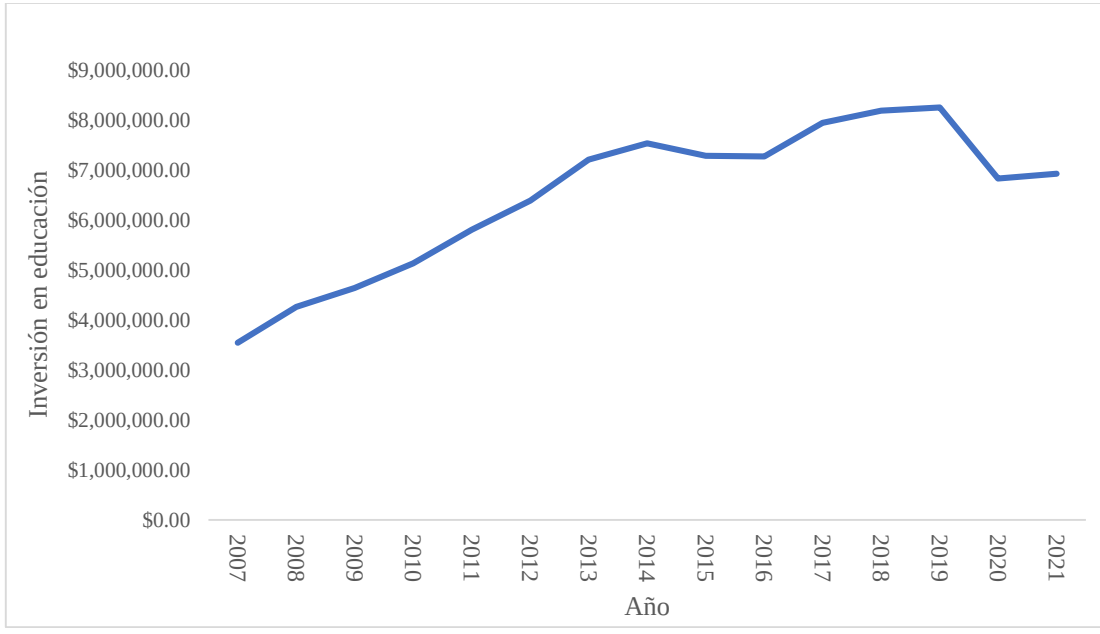

Figure 6 Line Graph of Ecuador's Education Expenditure (2007 - 2021)

Note. Line graph of education spending in Ecuador. Source: The World Bank (2023).

Normality Test

Table 2 presents the results of the normality test of the variables using the Shapiro-Wilk test. The significance values obtained for all the variables were greater than 0.05, which indicates that the null hypothesis of normality cannot be rejected. This suggests that the data of the variables analyzed follow a normal distribution, which allows the use of parametric statistical techniques that assume this characteristic in the data.

Normality tests		
Variables	Shapiro-Wilk	
	Estadístico	Sig.
ICE	0,921	0,199
IED	0,957	0,645
TradeBalance	0,988	0,998
EducationExpenditure	0,914	0,156
StudentsHigher	0,933	0,302
Health PIB	0,943	0,426

Table 2 Normality Test of the Study Variables

Note. Normality test for each of the variables studied.

Correlation Between the ECI and Macroeconomic Variables

			1	2	3	4	5
Pearson's r	1. ECI	r	1				
		Sig. (bilateral)					
	2. Balance of payments	r	0,393	1			
		Sig. (bilateral)	0,147				
	3. FDI	r	-0,502	-0,271	1		
		Sig. (bilateral)	0,057	0,328			
	4. AlumSup	r	-,566*	-,618*	,535*	1	
		Sig. (bilateral)	0,028	0,014	0,040		
	5. HealthGDP	r	-,788**	-0,461	,563*	,749**	1
		Sig. (bilateral)	0,000	0,084	0,029	0,001	

Table 3 Pearson's Correlation for Study Variables

Note. Pearson correlation values for the variables studied.

Trade balance (r = 0.393, p = 0.147):

The positive correlation between the ECI and the trade balance suggests that a higher trade surplus could be associated with greater economic sophistication. However, since the significance value (p = 0.147) is above the common threshold of 0.05, this relationship is not statistically significant. [44] argue that countries with a more diversified and sophisticated productive structure tend to show better performances in foreign trade, which could explain this relationship.

Foreign Direct Investment (FDI) (r = -0.502, p = 0.057):

A negative correlation is observed between FDI and ECI, suggesting that a greater flow of foreign investment does not necessarily contribute to the sophistication of the Ecuadorian economy. This result could be interpreted in light of [7] theory of endogenous technological change, where the type of investment is a determinant in the generation of knowledge and technological improvements. The relationship is not statistically significant at 5%, but it is close to the threshold (p = 0.057), indicating that there might be a trend that deserves further exploration.

Student production in higher education (AlumSup) (r = -0.566, p = 0.028):

The negative and statistically significant correlation at 5% suggests that a higher number of higher education graduates is associated with lower economic complexity. This finding could be contrary from [9] human capital theory, which argues that more education should boost economic development, however, in the Ecuadorian context, this could reflect problems in the

quality of education, the non-employability of graduates in key sectors of the economy, or mismatches between academic training and the needs of the productive market.

Health expenditure as a percentage of GDP (HealthGDP) (r = -0.788, p = 0.000):

A strong and highly significant negative correlation (p < 0.01) is identified between ECI and health spending, this indicates that higher health spending is associated with lower economic complexity. This result could reflect that in periods where the state allocates more resources to health, investment in strategic sectors for productive sophistication is reduced. [9] mentions that human capital is fundamental for growth, but if health spending responds to health crises or structural problems, it could divert resources from areas that enhance competitiveness and innovation. Health spending boosts economic development by improving productivity, reducing mortality and promoting equity in access to services, also acting as a macroeconomic stabilizer that favors sustainable growth [45].

Multiple Linear Recession Assumptions

Assumption	Results			
Autocorrelation	Durbin-Watson test			
	DW = 1.6294, p-value = 0.08742			
Homoscedasticity	Breusch-Pagan test			
	BP = 3.5459, df = 4, p-value = 0.4709			
	White test			
	BP = 4.2585, df = 2, p-value = 0.1189			
Multicollinearity	IED	Balanza	AlumSuper	SaludPIB
	1,542299	1,632781	3,056376	2,488191
Normality of residuals	Exact one-sample Kolmogorov-Smirnov test			
	D = 0.16669, p-value = 0.7394			
Model specification	RESET test			
	RESET = 1.4278, df1 = 2, df2 = 8, p-value = 0.2949			

Table 4 Multiple Linear Regression Assumptions

Note: Assumptions necessary for a correct application of the model.

The analysis of the assumptions of the multiple linear regression model allows validating the efficiency of the ordinary least squares estimator and guaranteeing reliable inferences. Regarding the autocorrelation of the residuals, the Durbin-Watson test (DW = 1.6294, p-value = 0.08742) does not allow rejecting the null hypothesis of absence of serial correlation at 5% significance, suggesting that the errors are independent, homoscedasticity is evaluated by the Breusch-Pagan tests (BP = 3. 5459, p-value = 0.4709) and White (BP = 4.2585, p-value = 0.1189), their high p-values confirm the absence of evidence to reject the hypothesis of constant variance in the residuals, thus fulfilling this essential assumption of the model.

On the other hand, multicollinearity is analyzed through the variance inflation factors (VIF), observing that the variables all variables are within the acceptable threshold (< 5), validated with the Kolmogorov-Smirnov test (D = 0.16669, p-value = 0. 7394), does not allow rejecting

normality, assuring the validity of the parametric tests, and finally, the model specification, evaluated by the RESET test (F = 1.4278, p-value = 0.2949), does not indicate problems of functional misspecification, so that overall, the results suggest that the model complies with the fundamental assumptions for a valid and efficient linear regression.

Multiple Linear Regression

Table 5 shows the results of the multiple linear regression model, with an R^2 of 0.6334 and an adjusted R^2 of 0.4867, the model explains approximately 48.67% of the variability of the ECI, indicating a moderate fit, the F-test (F = 4.319, p-value = 0. 0276) suggests that, as a whole, the explanatory variables have a significant effect on the dependent variable at the 5% significance level, however, at the individual level, only the variable HealthGDP is significant (p = 0.0256), indicating that health spending relative to GDP has a negative and statistically relevant impact on the ECI, while the other variables (FDI, trade balance and students in higher education) do not show significant effects in the model.

MODELO 1				
Call:				
lm(formula = ECI ~ IED + Balanza + AlumSuper + SaludPIB, data = data)				
Residuals:				
Min	1Q	Median	3Q	Max
-0.17025	-0.08806	-0.02685	0.07057	0.22455
Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.820e-02	3.852e-01	0.047	0.9633
IED	-5.371e-11	1.212e-10	-0.443	0.6672
Balanza	9.629e-12	2.848e-11	0.338	0.7423
AlumSuper	3.440e-05	8.573e-05	0.401	0.6967
SaludPIB	-1.565e+01	5.972e+00	-2.621	0.0256 *

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				
Residual standard error: 0.1351 on 10 degrees of freedom				
Multiple R-squared: .6334,	Adjusted R-squared: 0.4867			
F-statistic: 4.319 on 4 and 10 DF, p-value: 0.0276				

Table 5 Ordinary Least Squares Model 1 For Ecuador's Macroeconomic Variables

Note. OLS Of the Study Variables.

Continuing with the analysis, a second simple linear regression model was developed with the purpose of exclusively examining the relationship between the economic complexity index and health spending, this variable was previously identified as the only significant variable in the

multiple linear regression, so it was considered pertinent to delve into its impact on economic complexity.

MODELO 2				
Call:				
lm(formula = ECI ~ SaludPIB, data = data)				
Residuals:				
Min	1Q	Median	3Q	Max
-0.14736	-0.08776	-0.03538	0.07804	0.24732
Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.1621	0.2379	0.681	0.507756
SaludPIB	-15.5887	3.3737	-4.621	0.000479 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1				
Residual standard error: 0.1204 on 13 degrees of freedom				
Multiple R-squared: .6216,	Adjusted R-squared: 0.5924			
F-statistic: 21.35 on 1 and 13 DF, p-value: 0.0004793				

Table 6 Linear Regression for the Macroeconomic Proxy Variable for Ecuador

Note: Second linear regression model for health spending on Ecuador's economic complexity index.

The results presented in Table 6 indicate that the estimated coefficient of health spending is -5.5887, with a p-value of 0.000479, which confirms a negative and highly significant impact on the ECI at 1% confidence level, suggesting that an increase in health spending, holding all else constant, is associated with a decrease in economic complexity. The model presents an adjusted R^2 of 0.5924, indicating that approximately 59.24% of the variability of ECI is explained by HealthGDP, furthermore, the F-test (F = 21.35, p-value = 0.000479) confirms that the model is statistically significant overall.

The regression model confirmed that health spending is the only variable statistically significant in explaining the variability of the ECI; this finding supports the hypothesis that an inadequate allocation of resources to sectors of low productive complexity limits economic development (Carpio et al., 2021). The absence of significance in other variables suggests that the relationship between the ECI and the macroeconomic environment is more complex than expected and requires a more detailed analysis of the quality of foreign investment and the country's productive structure.

Hypotheses

Multiple Linear Regression

a) Logical model

H_0: The macroeconomic environment does not significantly affect Ecuador's economic complexity.

H_1: The macroeconomic environment significantly affects Ecuador's economic complexity.

b) Mathematical model.

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$

H_1: At least one of the coefficients of the macroeconomic variables is different from 0.

c) Statistical model.

The multiple linear regression model is expressed as:

$$ICEt=\beta 0+\beta 1IEDt+\beta 2Balanzat+\beta 3AlumSupert+\beta 4SaludPIBt+\varepsilon t$$

Where:

$ICEt$ represents the Economic Complexity Index in period t.

$IEDt$, $Balanzat$, $AlumSupert$ and $SaludPIBt$ are the explanatory macroeconomic variables.

$\beta 0$ is the intercept, βi the regression coefficients and εt the error term.

Decision rule.

At a 95% confidence level, if the p-value of the F-statistic is less than 0.05, the null hypothesis is rejected and the alternative hypothesis is accepted, confirming that at least one macroeconomic variable has a significant impact on economic complexity.

Model Results

As shown in Table 6, since the p-value (0.0276) is less than the significance threshold of 5%, the null hypothesis is rejected and the alternative hypothesis is accepted, confirming that the macroeconomic environment significantly affects Ecuador's economic complexity.

Discusión

The results obtained in this study allow us to analyze the relationship between the macroeconomic environment and the economic complexity of Ecuador from three different approaches:

The analysis of the line diagrams showed fluctuations in the evolution of the economic complexity index (ECI) and its main macroeconomic determinants; a sustained decrease in the ECI was observed during periods of economic crisis, which suggests a high sensitivity of the Ecuadorian productive structure to changes in the macroeconomic context; this behavior can be explained by the theory of economic complexity [1], which states that economies with less productive diversification are more vulnerable to external shocks. Empirical studies have shown that countries with an export basket concentrated in low value-added products tend to experience greater volatility in their economic growth [46]. In the case of Ecuador, dependence on primary sectors, such as oil and agricultural products, has been a determining factor in the evolution of

its economic complexity, since international price shocks have negatively impacted its export performance and, therefore, its ECI [47]. According to the literature on structural change, economic resilience depends on the capacity of countries to diversify their productive matrix and develop knowledge-intensive sectors [48].

The Pearson correlation between the ECI and key macroeconomic variables, here a significant negative relationship was identified between the ECI and health spending as a percentage of GDP ($r = -0.788$, $p < 0.01$), indicating that higher health spending may not be directed towards sectors that foster productive sophistication, similarly, the negative correlation between the ECI and the number of higher education graduates ($r = -0.566$, $p < 0.05$) suggests that the educational system is not generating the human capital needed to strengthen the country's productive structure [49]in contrast, the trade balance presented a positive correlation with the ECI, although not significant, which reinforces the idea that a more diversified economy can improve its trade position [50].

The negative relationship with the only representative variable being health spending and the economic complexity index can be explained by the allocation of resources to sectors with low productive complexity, although health is a fundamental pillar of human capital, its impact on economic sophistication depends on how spending is structured, in economies where a large proportion of the budget is allocated to the primary sector, instead of promoting knowledge-intensive sectors, the impact on productive diversification may be limited [40]. According to [47], in countries with economies dependent on the extraction of natural resources, investment in health may not translate into significant improvements in innovation or advanced technological sectors, since the productive structure continues to be oriented towards less complex activities, so that the lack of integration of health policies with innovation and technological development strategies could be limiting the expected positive impact on the ECI, reinforcing an economic structure based on traditional comparative advantages instead of one based on dynamic and technological capabilities.

Overall, these results underscore the need to reformulate public policies to direct investment in health and education towards sectors that promote innovation and technological development, as well as to strengthen productive diversification strategies and improve the linkage between foreign investment and sustainable economic growth in Ecuador.

Funding

This research received no external funding. The APC was funded by Universidad Tecnológica Indoamérica.

Acknowledgments:

A thank you to Universidad Tecnológica Indoamérica for its support in the development of this research under the project IIDI-001-23.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

C. A. Hidalgo and R. Hausmann, “The building blocks of economic complexity,” Proc. Natl. Acad. Sci., vol. 106, no. 26, pp. 10570–10575, Jun. 2009, doi: 10.1073/pnas.0900943106.

A. Núñez-Naranjo, X. Morales-Urrutia, and L. Simbaña-Taipe, “Social capital, education, and subjective

well-being in Ecuador," Front. Sociol., vol. 9, no. 1417538, 2024, doi: 10.3389/fsoc.2024.1417538.
P. Mealy and A. Teytelboym, "Economic complexity and the green economy," Res. Policy, vol. 51, no. 8, p. 103948, Oct. 2022, doi: 10.1016/j.respol.2020.103948.
J. E. Gomez-Gonzalez, J. M. Uribe, and O. M. Valencia, "Does economic complexity reduce the probability of a fiscal crisis?," World Dev., vol. 168, p. 106250, Aug. 2023, doi: 10.1016/j.worlddev.2023.106250.
B. Shahmoradi, R. Hafezi, and P. Chiniforooshan, "Industrial Development Policies Based on Economic Complexity Under Plausible Scenarios: Case of Iran 2027," J. Knowl. Econ., vol. 15, no. 2, pp. 6578–6603, May 2023, doi: 10.1007/s13132-023-01354-1.
A. F. Núñez-Naranjo, D. M. L. Haro, J. P. M. Mesías, and M. J. S. Sarzosa, "Firm Size and Growth in Ecuador's Trade Sector: An Analysis from an Industrial Economics Perspective," J. Ecohumanism, vol. 3, no. 6, pp. 2060–2073, Sep. 2024, doi: 10.62754/joe.v3i6.4159.
P. M. Romer, "Endogenous Technological Change," J. Polit. Econ., vol. 98, no. 5, Part 2, pp. S71–S102, Oct. 1990, doi: 10.1086/261725.
J. A. Schumpeter, The Theory of Economic Development. Routledge, 2021. doi: 10.4324/9781003146766.
G. S. Becker, Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education. 1975. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.nber.org/system/files/chapters/c3730/c3730.pdf
E. Brynjolfsson and A. McAfee, The second machine age: Work, progress, and prosperity in a time of brilliant technologies. 2014. [Online]. Available: https://books.google.com.ec/books?hl=es&lr=&id=WiKwAgAAQBAJ&oi=fnd&pg=PA1&dq=Brynjolfsson,+E.,+%26+McAfee,+A.+(2014).+The+second+machine+age:+Work,+progress,+and+prosperity+in+a+time+of+brilliant+technologies.+W.+W.+Norton+%26+Company.&ots=4-XqSd4xec&sig=WfDHci9q19znoSP5GchxsFp_i6A#v=onepage&q=Brynjolfsson%2C E.%2C %26 McAfee%2C A. (2014). The second machine age%3A Work%2C progress%2C and prosperity in a time of brilliant technologies. W. W. Norton %26 Company.&f=false
S. Velamva and A. Phiri, "Growing through knowledge: examining the knowledge–complexity relationship in Africa," Dev. Stud. Res., vol. 11, no. 1, Dec. 2024, doi: 10.1080/21665095.2024.2392496.
P. Bhujabal, N. Sethi, and P. C. Padhan, "ICT, foreign direct investment and environmental pollution in major Asia Pacific countries," Environ. Sci. Pollut. Res., vol. 28, no. 31, pp. 42649–42669, Aug. 2021, doi: 10.1007/s11356-021-13619-w.
W. S. Krokeyi and B. O. Niyekpemi, "Human capital and economic growth nexus in Nigeria," J. Glob. Econ. Bus., vol. 2, no. 6, pp. 31–49, Jul. 2022, doi: 10.31039/jgeb.v2i6.57.
M. S. Khan, "Human capital and economic growth in Pakistan," Pak. Dev. Rev., vol. 44, no. 4 PART I, pp. 455–471, 2005, doi: 10.30541/v44i4ipp.455-478.
Y. Zhang, S. Kumar, X. Huang, and Y. Yuan, "Human capital quality and the regional economic growth: Evidence from China," J. Asian Econ., vol. 86, p. 101593, Jun. 2023, doi: 10.1016/j.asieco.2023.101593.
K. Zheng, X. Zheng, Y. Yang, and J. Chang, "Advancing higher education and its implication towards sustainable development: Moderate role of green innovation in BRI economies," Heliyon, vol. 9, no. 9, p. e19519, Sep. 2023, doi: 10.1016/j.heliyon.2023.e19519.
M. Ahmad, Z. Ahmed, A. Majeed, and B. Huang, "An environmental impact assessment of economic complexity and energy consumption: Does institutional quality make a difference?," Environ. Impact Assess. Rev., vol. 89, p. 106603, Jul. 2021, doi: 10.1016/j.eiar.2021.106603.
[18] X. Lin, Y. Zhao, M. Ahmad, Z. Ahmed, H. Rjoub, and T. S. Adebayo, "Linking Innovative Human Capital, Economic Growth, and CO2 Emissions: An Empirical Study Based on Chinese Provincial

Panel Data," Int. J. Environ. Res. Public Health, vol. 18, no. 16, p. 8503, Aug. 2021, doi: 10.3390/ijerph18168503.
M. E. Porter, "The Competitive Advantage of Nations," Free Press. [Online]. Available: https://hbr.org/1990/03/the-competitive-advantage-of-nations
K. A. Sanusi, S. Ferreira-Schenk, and Z. Dickason-Koekemoer, "Trade balance, exchange rate performance and economic growth: Evidence from Southern African Development Community.," Expert J. Econ., vol. 11, no. 1, 2023, [Online]. Available: https://economics.expertjournals.com/23597704-1101/
B. Arthur, M. Saha, F. A. Sarpong, and K. D. Dutta, "Unlocking Africa's potential: The transformative power of foreign direct investment for sustainable development," Heliyon, vol. 10, no. 5, p. e26507, Mar. 2024, doi: 10.1016/j.heliyon.2024.e26507.
L. K. Chu and D. P. Hoang, "How does economic complexity influence income inequality? New evidence from international data," Econ. Anal. Policy, vol. 68, pp. 44–57, Dec. 2020, doi: 10.1016/j.eap.2020.08.004.
R. Hausmann, C. A. Hidalgo, S. Bustos, M. Coscia, A. Simoes, and M. A. Yildirim, The Atlas of Economic Complexity. The MIT Press, 2014. doi: 10.7551/mitpress/9647.001.0001.
P. M. García and A. López, "La inversión extranjera directa: Definiciones, determinantes, impactos y políticas públicas," Washington, D.C., Aug. 2020. doi: 10.18235/0002601.
[25] H. W. Chesbrough, "Open Innovation: The New Imperative for Creating and Profiting from Technology," Eur. J. Innov. Manag., vol. 7, no. 4, pp. 325–326, Dec. 2004, doi: 10.1108/14601060410565074.
T. T. Osinubi and F. M. Ajide, "Foreign direct investment and economic complexity in emerging economies," Econ. J. Emerg. Mark., pp. 245–256, Oct. 2022, doi: 10.20885/ejem.vol14.iss2.art9.
M. Torres Freire and J. A. Campuzano Vásquez, "Impacto de la Balanza Comercial en el crecimiento económico ecuatoriano, período 1990-2019," Rev. Científica y Tecnológica UPSE, vol. 8, no. 1, pp. 42–47, Jun. 2021, doi: 10.26423/rctu.v8i1.554.
P. M. Aguilar, D. B. Maldonado, and S. S. Solorzano, "Incidencia de la balanza comercial en el crecimiento económico del Ecuador: análisis econométrico desde Cobb Douglas, período 1980-2017," Espacios, vol. 41, no. 3, pp. 1–10, 2020, [Online]. Available: http://ww.w.revistaespacios.com/a20v41n03/a20v41n03p10.pdf
H. Kopnina, "Education for the future? Critical evaluation of education for sustainable development goals," J. Environ. Educ., vol. 51, no. 4, pp. 280–291, Jul. 2020, doi: 10.1080/00958964.2019.1710444.
M. A.- Rehman, S. Ghaffar, K. Shahzadi, and R. Ghazanfar, "Human Capital Formation and Economic Growth in Emerging Asia: Empirical Evidence Using Panel Data," Rev. Appl. Manag. Soc. Sci., vol. 3, no. 2, pp. 205–212, Sep. 2020, doi: 10.47067/ramss.v3i2.54.
M. Aydin, T. Degirmenci, O. Bozatli, and D. Balsalobre-Lorente, "Fresh evidence of the impact of economic complexity, health expenditure, natural resources, plastic consumption, and renewable energy in air pollution deaths in the USA? An empirical approach," Sci. Total Environ., vol. 921, p. 171127, Apr. 2024, doi: 10.1016/j.scitotenv.2024.171127.
C. Chatfield, The Analysis of Time Series. Chapman and Hall/CRC, 2003. doi: 10.4324/9780203491683.
D. N. Gujarati and D. C. Porter, Basic Econometrics, 5th ed. McGraw-Hill., 2009. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://ucanapplym.s3.ap-south-1.amazonaws.com/RGU/notifications/E_learning/0nline_study/Basic-Econometrics-5th-Ed-Gujarati-and-P.pdf
W. A. Lewis, "Economic Development with Unlimited Supplies of Labour," Manchester Sch., vol. 22, no. 2, pp. 139–191, May 1954, doi: 10.1111/j.1467-9957.1954.tb00021.x.
D. Foray and B. Å. Lundvall, "The knowledge-based economy: From the economics of knowledge to the

learning economy," Econ. Impact Knowl., pp. 115–122, 2009, doi: 10.1016/b978-0-7506-7009-8.50011-2.
G. Gereffi, "The Organization of Buyer-Driven Global Commodity Chains: How US Retailers Shape Overseas Production Networks," in Global Value Chains and Development, Cambridge University Press, 1994, pp. 43–71. doi: 10.1017/9781108559423.003.
J. H. Dunning, "Toward an Eclectic Theory of International Production: Some Empirical Tests," J. Int. Bus. Stud., vol. 11, no. 1, pp. 9–31, Mar. 1980, doi: 10.1057/palgrave.jibs.8490593.
S. Mishra, I. Tewari, and S. Toosi, "Economic complexity and the globalization of services," Struct. Chang. Econ. Dyn., vol. 53, pp. 267–280, Jun. 2020, doi: 10.1016/j.strueco.2020.03.002.
World Health Organization., "Global health expenditure database." [Online]. Available: https://apps.who.int/nha/database
Carpio Carlos, Pablo Joseph, and Solano Bianca, "La Incidencia De La Inversion Publica En El Sistema De Salud," Rev. Compend. Cuad. Econ. y Adm., vol. 8, no. 2, pp. 145–164, 2021.
E. Cossío, "Reformas estructurales y crecimiento económico en mercados emergentes: un enfoque de complejidad económica," Universidad de LIma, 2020. doi: 10.26439/ulima.tesis/11224.
D. J. Deming, "Four Facts about Human Capital," J. Econ. Perspect., vol. 36, no. 3, pp. 75–102, Aug. 2022, doi: 10.1257/jep.36.3.75.
Y. Xu and M. García, "Análisis histórico de la vinculación entre la educación superior y el desarrollo económico en China," Rev. Cuba. Educ. Super., vol. 40, no. 1, p. Epub 01-Abr-2021, 2021, [Online]. Available: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0257-43142021000100007&lng=es&nrm=iso&tlng=es
L. Zapata-Cantu and F. González, "Challenges for Innovation and Sustainable Development in Latin America: The Significance of Institutions and Human Capital," Sustainability, vol. 13, no. 7, p. 4077, Apr. 2021, doi: 10.3390/su13074077.
U. Beylik, U. Cirakli, M. Cetin, E. Ecevit, and O. Senol, "The relationship between health expenditure indicators and economic growth in OECD countries: A Driscoll-Kraay approach," Front. Public Heal., vol. 10, Nov. 2022, doi: 10.3389/fpubh.2022.1050550.
C. Carrasco, "Sector externo, complejidad y crecimiento económico desde la perspectiva latinoamericana," 360 Rev. Ciencias la Gestión, no. 6, pp. 196–208, Sep. 2021, doi: 10.18800/360gestion.202106.009.
M. M. Hasan and F. Du, "The role of foreign trade and technology innovation on economic recovery in China: The mediating role of natural resources development," Resour. Policy, vol. 80, p. 103121, Jan. 2023, doi: 10.1016/j.resourpol.2022.103121.
B. Rivera, M. Leon, G. Cornejo, and H. Florez, "Analysis of the Effect of Human Capital, Institutionality and Globalization on Economic Complexity: Comparison between Latin America and Countries with Greater Economic Diversification," Economies, vol. 11, no. 8, p. 204, Jul. 2023, doi: 10.3390/economies11080204.
B.-Å. Lundvall, National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning. Anthem Press, 2010. Accessed: Mar. 28, 2025. [Online]. Available: http://www.jstor.org/stable/j.ctt1gxp7cs
M. Markaki and G. Economakis, "INTERNATIONAL STRUCTURAL COMPETITIVENESS AND THE HIERARCHY IN THE WORLD ECONOMY: Theoretical and Empirical Research Evidence," World Rev. Polit. Econ., vol. 12, no. 2, pp. 195–219, 2021, Accessed: Mar. 28, 2025. [Online]. Available: https://www.jstor.org/stable/48676086