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MASTER
Management and Industrial Strategy

MASTER´S FINAL WORK
Dissertation

Economic complexity as a determinant of human development: a cross-sectional analysis

João Américo Guilhoto Marques Castelo

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Masters

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SUPERVISION:

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GLOSSARY

HDI- Human Development Index

ECI- Economic Development Index

PCI- Product Complex Index

GDP- Gross Domestic Product

Resumo

Este estudo tem como objetivo analisar a relação entre complexidade económica e desenvolvimento humano, utilizando os respetivos índices - Index de Complexidade Económica (ICE) e Index de Desenvolvimento Humano (IDH). A análise centra-se no ano de 2023, por ser o período mais recente para o qual se encontram disponíveis todos os dados necessários.

Com vista a isolar o efeito específico da complexidade económica no desenvolvimento humano, procedeu-se à remoção da multicolinearidade entre o ICE e o Produto Interno Bruto (PIB) per capita. Esta abordagem metodológica permite verificar se, na ausência deste efeito confundidor, persiste uma relação significativa entre as variáveis em estudo.

Adicionalmente, foram considerados os diferentes níveis de desenvolvimento humano definidos pelo HDI: muito alto, alto, médio e baixo. Esta estratificação possibilita a análise diferencial do impacto da complexidade económica em função do nível de desenvolvimento dos países.

Os resultados obtidos revelam a existência de uma relação significativa entre complexidade económica e desenvolvimento humano nos países menos desenvolvidos, mesmo após o controlo dos efeitos do PIB per capita. Contudo, esta relação não se verifica nos países com níveis mais elevados de HDI, sugerindo que o impacto da complexidade económica no desenvolvimento humano varia consoante o estágio de desenvolvimento dos países.

Palavras-chave: Complexidade económica, desenvolvimento humano, desenvolvimento económico

Abstract

This study aims to analyze the relationship between economic complexity and human development, using the respective indices - Economic Complexity Index (ECI) and Human Development Index (HDI). The analysis focuses on the year 2023, as it represents the most recent period for which all necessary data are available.

To isolate the specific effect of economic complexity on human development, multicollinearity between the ECI and GDP per capita was removed. This methodological approach allows for verification of whether, in the absence of this confounding effect, a significant relationship persists between the variables under study.

Additionally, the different levels of human development defined by the HDI were considered: very high, high, medium, and low. This stratification enables differential analysis of the impact of economic complexity according to countries' development levels.

The results obtained reveal the existence of a significant relationship between economic complexity and human development in less developed countries, even after controlling for the effects of GDP per capita. However, this relationship is not verified in countries with higher HDI levels, suggesting that the impact of economic complexity on human development varies according to countries' development stage.

Keywords: Economic complexity, human development, economic development

JEL CODES: O15, O11, O14

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1. Introduction

This study examines the relationship between two widely used economic indices: the Economic Complexity Index (ECI) and the Human Development Index (HDI), specifically investigating how the former influences the latter. Both indices have substantial academic foundations and have been extensively applied across various fields of economics and development studies for many years (Hidalgo, & Hausmann, 2009) (Haq, 1995).

The relationship between these two indices is essential, as they are among the more recent and widely used economic indicators for tracking changes in the economic landscape and quality of life in a country. Understanding the relationship between the two can allow different policies to be implemented based on what can improve people's lives and for whom.

The structure of this work includes a literature review exploring human development and the index used to calculate it, followed by the same approach for industrial development, with a focus on economic complexity and its associated index. The next step is the methodology, where the approach used to answer the questions in this work is explained. Following this, we present our findings as well as the discussion, where we attempt to explain the reasons behind these findings and the possible implications these results can have for economic policies.

The ECI is based on the concept of economic complexity and is primarily used to measure the relationships between goods and countries in global trade networks (Hidalgo & Hausmann, 2009). It assigns complexity values to both individual products and countries' overall production capabilities. This framework enables comparisons between different products and countries based on their respective complexity levels through specialized indices, such as the ECI for measuring countries' complexity and the Product Complexity Index (PCI) for measuring products' complexity (Hidalgo & Hausmann, 2009). However, the latter is not utilized in this study.

HDI is an index that measures human development, representing one of the most widely used indicators of quality of life across different countries' populations. By utilizing this index, we can compare the developmental performance of various nations and assess their relative progress in human welfare (UNDP, 1990).

The objective of this work is to investigate the potential relationship between these two indices, examining whether changes in a country's economic complexity, as measured by the ECI, have a meaningful impact on its development level, as measured by the HDI. The main reason to believe that it is possible for the two indicators, as well as their respective complexity and human development, to be connected is primarily the education and know-how connection. While the ECI tends to measure the know-how of countries, the HDI measures, at least in part, education. These two aspects are related to each other, and so it is expected that the respective indexes will be as well.

Despite the theoretical importance of this relationship, empirical evidence has been surprisingly mixed and inconclusive. Previous studies have faced significant methodological challenges that may explain these contradictory findings. Lapatinas (2016) found no concrete evidence of the relationship between ECI and HDI variation. Although this is not exactly the same research design, it is one of the closest to this study, using panel data from 1965-2005. Meanwhile, Soyyigit (2019) identified variable relationships in G20 countries with different effects for developed versus developing nations. These inconsistent results may stem from the temporal complexity inherent in multi-year analyses, where structural changes, measurement evolution, and varying lag effects can obscure underlying relationships.

This study addresses these methodological limitations through a novel single-year cross-sectional approach using the most recent available data (2023). By eliminating temporal confounding factors while maintaining sufficient cross-country variation, this design provides a more transparent lens for examining the contemporary relationship between the ECI and HDI. Additionally, we address a critical oversight in previous research: the potential multicollinearity between ECI and Gross Domestic Product

(GDP) per capita, which can distort the apparent relationship between complexity and development.

Therefore, the primary research questions in this work are: Does the economic complexity of a country have any meaningful impact on its human development? Does ECI have an independent effect on human development after controlling GDP per capita? Is this impact different in countries with different levels of development? If so, in which development stage does the ECI stop having an effect on development?

2. Literature Review

This section concentrates on the theoretical frameworks that underpin this research. It introduces the concepts of industrial development and economic complexity, provides a comprehensive review of Human Development and the Human Development Index (HDI), including their applications and calculation methodologies, and concludes with a review of prior literature examining the relationship between human development and economic complexity.

2.1. Human Development

The examination of human development is closely related to its widespread use as a measure of quality of life and the methodology underlying its calculation, which uses the availability of choices to measure development. Human development encompasses more than GDP growth, as access to income represents only one component of people's choices. Human development is fundamentally concerned with capabilities, not only those directly related to basic needs, such as health and knowledge, but also those without direct links that indirectly influence development, such as work and leisure opportunities (UNDP, 1990).

Unlike income per capita as a proxy for well-being, human development adopts a multidimensional approach to understanding well-being. The theoretical foundation of human development is grounded in Sen's capability approach, which serves as the underlying framework for conceptualizing human development. Sen's capability approach focuses neither on wealth nor on utility measures to evaluate people's quality of life. It operates through the concept of human functioning, which represents the things a person values being or doing. Capabilities, in turn, refer to people's ability to achieve these functioning. This approach recognizes humans as heterogeneous within the economy and acknowledges that people are diverse, having different functioning based on gender, social class, age, among other factors. Through this framework, it becomes possible to attempt meaningful comparisons of living quality across different countries or regions (Clark, 2005)

Another rationale for utilizing human development is that it enables institutions to better understand the potential trade-offs between different policy choices, facilitating more informed decision-making. Furthermore, adopting a multidimensional perspective allows for moving beyond the commodity viewpoint, which, while often the most prevalent and easiest-to-use approach, tends to misinterpret fundamental human needs. To serve as a comparable indicator, human development must be presented as an index, which enables comparisons through the Human Development Index (HDI) (Alkire, 2002).

2.1.1. Calculation of HDI

The HDI is measured on a scale from 0 to 1. This measurement is calculated using the geometric mean of three distinct components, each representing a different category. These components include income, measured as Gross National Income (GNI) per capita with purchasing power parity (PPP) to better compare buying power across different countries. The International Monetary Fund (IMF) and the World Bank collect price data for various products to facilitate more accurate purchasing power comparisons across countries. Education is measured using two different indicators. First, the average number of years of education among the adult population, which represents the average number of years of schooling that individuals aged 25 or older have acquired during their lifetime. The second education indicator is the expected number of years of education for children at the time of school enrollment, representing the total number of years of schooling scheduled for children at admission, provided that existing enrollment rates for specific ages remain constant throughout the child's educational journey (Boban et al., 2020). The third component is life expectancy at birth, which reflects the overall quality of health and nutrition of the population in question (UNDP, 2023).

The HDI serves as a comparative tool, meaning its values are only meaningful when compared across countries. For instance, the index enables rankings and facilitates comparisons. One significant comparison the HDI enables involves assessing a specific country's ranking against its GDP ranking. When both rankings align, this suggests harmony between the country's resources and its development outcomes. Conversely, if a country has a higher GDP ranking than its HDI ranking, this may indicate underutilization of resources, leading to less development than anticipated, with benefits accruing to only a small segment of the population. The final scenario occurs when the HDI ranking surpasses the GDP ranking, indicating that the country's resources are being effectively employed for development purposes (Boban et al., 2020).

2.1.2. History of HDI

Before the establishment of the HDI, the capability approach had already been developed and used as a framework for understanding poverty and inequality. This perspective on poverty and inequality was developed by Amartya Sen, enabling a new lens through which to view these issues by focusing on people's capabilities rather than solely on material wealth. This perspective emphasized the importance of education and specific services in measuring poverty and inequality, rather than relying exclusively on material wealth. Mahbub-ul-Haq later utilized this concept to create the HDI, applying the capabilities approach to assess societal well-being (Clark, 2005).

Since the HDI was first implemented in 1990, methodologies have evolved, although the core components—education, income, and life expectancy—have remained unchanged. One example is the evolution of education metrics without altering the underlying variables. A notable change was the switch from an arithmetic to a geometric mean in 2010, which ensured that percentage changes in each dimension

(GNI, education, life expectancy) have equal proportional weight in determining the overall HDI score, reducing the substitutability between dimensions (Boban et al., 2020).

2.1.3. Comparison with Other Indices

Several other indices attempt to measure social welfare, and although these are less widely known and used, they can reveal some shortcomings in the HDI and suggest possible improvements to this index. One of the main criticisms of the HDI is its lack of consideration for environmental and biodiversity factors. Unlike other indices, such as the Sustainable Development Index, the HDI does not account for ecological sustainability (Hickel, 2020). Other indices include the Index of Sustainable Economic Welfare (ISEW) and the Genuine Progress Indicator (GPI) (Lawn, 2003). Both make adjustments based on ecological and social costs that are not considered in traditional measures. While these can be useful for accounting purposes in some nations, they are not as comprehensive as the HDI in addressing development issues, as they lack the well-developed theoretical foundation that underlies the HDI, which is based on the capability approach (Hickel, 2020).

2.2. Industrial Development

Historically, industrial development was viewed as a process involving structural changes within the economy, considered the foundation of economic growth. Under this framework, industrial progress was thought to move linearly from primary to secondary and tertiary sectors. However, recent evidence challenges this view, demonstrating that countries with similar sectoral compositions can have vastly different development levels (Rodrik, 2006).

Over time, the understanding of industrial development has evolved in response to changes in sectoral structures, highlighting the growing importance of new areas within the industrial process. Innovation, particularly the creation and implementation of new technologies and improvements in operational efficiency, has become central to modern industrial development. The interconnectedness of industries is another key factor, as it influences both supply chains and demand patterns while enabling economies of scale, fostering specialization, and promoting knowledge spillovers. Furthermore, in many developing countries, the existence of surplus labor plays a critical role. In these contexts, excess labor can be reallocated from low-productivity sectors to more productive areas of the economy, contributing to overall growth and structural transformation (Kniivilä, 2007).

The discourse surrounding industrial development has undergone a significant transformation in recent years. A pivotal factor influencing a nation's industrial advancement is the diversification of its economy. This perspective challenges certain aspects of comparative advantage theory, which asserts that countries benefit from specializing in the production of specific goods. While specialization remains important, evidence suggests that its optimal benefits are realized only after a certain level of economic diversification has been established. When represented graphically, a country's income growth trajectory exhibits an inverse U-shape, with diversification plotted along the horizontal axis and specialization along the vertical axis. This relationship implies that diversification is necessary to reach a critical midpoint, after which specialization becomes essential for achieving maximum income growth. Given the fundamental role of diversification in fostering industrial development, a deeper understanding of this concept is warranted (Rodrik, 2006).

Despite the increasing emphasis in modern economies on services and technology, traditional sectors like manufacturing remain essential to discussions of industrial development. As noted by Rodrik (2013), manufacturing continues to be one of the main engines of structural transformation. A key reason is the strong and persistent relationship between manufacturing output growth and GDP growth. This relationship stems not only from the direct contribution of output but also from productivity spillovers that manufacturing generates, both within the sector and across the broader economy, exceeding those observed in services or agriculture (Thirlwall, 1983).

Another important aspect is the catch-up potential of the manufacturing sector. Unlike other sectors, manufacturing allows for more straightforward technology transfer and imitation, facilitating faster convergence with advanced economies, regardless of specific industrial policy. Moreover, manufactured goods tend to be more technologically sophisticated, increasing their value in global markets and making exports a key driver for fast-growing economies (Weiss & Jalilian, 2016).

To better understand these dynamics, analytical tools such as the Economic Complexity Index (ECI) offer valuable insights. The ECI captures the diversity and sophistication of a country's capabilities. These capabilities are not the same as those in Sen's capabilities approach, where they were mostly related to personal possibilities. Rather, these are capabilities related to production and economic structures present in countries, which tend to be tacit and non-tradable, like know-how. These are then measured in the ECI based on the products those capabilities produce (Vu, 2022). They are measured particularly in the manufacturing sector, and their links are seen in broader economic performance. By quantifying the complexity of what countries produce and export, the ECI helps explain why nations with more advanced and diversified manufacturing bases tend to experience sustained economic growth and human development gains (Hidalgo & Hausmann, 2009).

2.2.1. The Concept of Economic Complexity

Economic complexity is grounded in the concept that products vary in their knowledge requirements. Complex products demand intensive technical knowledge inputs, whereas simpler products may incorporate some technical knowledge but do not fundamentally depend on it for production. A country's economic complexity thus emerges from the sophistication of its products and the diversity of its product capabilities (Sepehrdoust, et al. 2019).

Understanding this complexity requires examining how knowledge is distributed and transmitted within economies. A core principle of economic complexity is that today's major economic challenges revolve around the systematic relationships between products and services and their interconnections. Central to this concept is knowledge, specifically its location, which is a fundamental tenet of economic complexity, as it is integral to every product, particularly the know-how associated with those products.

Building on this premise, it is possible to establish a framework of economic complexity and its geographical distribution. Although knowledge can be transferred from person to person, know-how is not as readily transmitted as other forms of knowledge. This is primarily because its transmission necessitates repetition, imitation, and feedback. Given the inherent limitations of individual know-how, a degree of personal specialization becomes essential (Balland et al., 2022).

It is important to distinguish between individual specialization and national economic specialization, as these are often inversely related. While individuals become increasingly specialized in specific domains, countries with high economic complexity typically produce a wide variety of goods and services, meaning that fewer individuals may possess the knowledge required for any single product. A complex product, therefore, is one that only a small number of people have the expertise to produce and that typically requires the integration of knowledge from multiple disciplines. Product complexity at the national or regional level is assessed by examining the economic significance of specific products and the depth of expertise required to produce them. Using this approach, we can calculate a country's complexity, which can then be ranked according to the ECI. This ranking allows us to compare the complexities of different countries and apply this information in various contexts, including predicting future products, assessing population dynamics, and formulating policies to promote long-term economic growth (Hidalgo & Hausmann, 2009). It is also important to note that the ECI is based on trade data, as it is not possible to achieve the same precision in production data as easily as it is in trade data (Albeaik et al., 2017).

2.2.2. Calculation Methods for the ECI

The calculation of the ECI is inherently recursive, meaning that an economy's complexity is determined not by factors outside the complexity calculations themselves, but by a cyclical calculation where the complexity of the product impacts the complexity of the country and vice versa. This makes products produced by fewer countries more complex, solely because few economies can produce that specific product, and those countries are already considered complex. This interdependence creates a feedback loop: countries that produce complex products are deemed complex, and vice versa as seen in the OEC website.

The ECI uses the revealed comparative advantage (RCA) to calculate whether a country has an advantage in its exports compared to other countries exporting the same product. This allows for a better comparison of the countries with different-sized economies (Hausmann et al, 2009). After this point, the Mcp in order to be relevant needs to be equal to 1; this matrix is calculated, having c as country and p for product, which allows the comparison of different countries. After this the complexity is then calculated following circular calculations as previously referred.

2.2.3. Real-Life Applications of Economic Complexity

To apply the Economic Complexity Index (ECI) effectively, it is essential first to consider the concept of relatedness. The relationship between products is a foundational aspect of economic complexity and is crucial for interpreting ECI findings. Relatedness helps predict future economic developments, specifically where new and distinct forms of production are likely to emerge, and which products will be manufactured in particular locations. This data can be categorized into different related areas, such as location, occupation, and industry specifications. The relationship between industries and occupations is often influenced by prior experience in similar occupations and industries. Location specifications pertain to the areas where various workers have been employed, regardless of the exact location. At the inception of a new pioneering firm, industrial and location-relatedness tend to be the most influential factors in determining the emergence of a new industry, excluding occupation-relatedness. For occupation-relatedness, there are ways to further categorize it into complementary (occupations used in the same activity), similar (identical occupations), and local synergies (occupations in the same cities), with the latter being the most relevant for predicting the entry or exit of new industries (Hidalgo, 2023).

Labor dynamics also intersect with relatedness. Since workers tend to move between related occupations and industries, relatedness can improve forecasts of workforce mobility and regional resilience. In areas with high relatedness, job losses tend to have less severe long-term impacts, as workers can more easily transition to other, similar roles. This dynamic also helps predict migration patterns and supports regional planning. Moreover, relatedness contributes to economic sustainability. A more diversified economy, one where industries are closely connected, tends to be more resilient and adaptive, which is especially important in the transition to a green economy (Hidalgo, 2023).

From a policy perspective, relatedness can guide decisions about which industries are most likely to thrive in a given country or region. However, data analysis reveals that the most common sectors tend to have an intermediate level of relatedness rather than a high one, as might be expected (Uhlbach et al. 2017).

2.2.4. The Difference Between Lower and Higher ECI Countries

One notable difference between countries with high and low ECI is output volatility. More diversified countries have a variety of products, and so the effects of output volatility are mitigated. This effect is more relevant in countries with higher incomes, as those with lower incomes tend to require more time to establish the relationship between the ECI and output volatility. This means that, despite complexity having an effect on output volatility, income is still very relevant to output volatility. As a result, these economies are more susceptible to fluctuations in international trade, as their lower economic complexity leaves them more exposed to external shocks (Breitenbach et al., 2017).

Moreover, various forms of national risk, including economic, financial, and political risks, tend to be very important factors in determining the relationship between the ECI and income inequality. Countries with lower risks tend to have a stronger relationship between improvements in productive structure and reductions in inequality (Lee & Wang, 2020).

A fundamental insight into the ECI framework is its emphasis on the specialization of economic activities and their link to income inequality. Countries where income tends to be higher are also those where the ECI is higher, and the same applies to lower-income countries having lower ECI values. This factor is directly related to the capabilities in countries with lower income, as these tend to have fewer capabilities, and those tend also to be fewer complex ones (Felipe et al., 2012).

2.2.5. Criticism of the ECI

One of the primary criticisms of the Economic Complexity Index (ECI) concerns its data limitations, particularly its reliance on export data. This focus tends to overlook significant portions of domestic production, especially in countries with large internal markets. Additionally, critics argue that the ECI insufficiently accounts for diversification. For instance, a country producing a single high-complexity product may be ranked more favorably than a country producing a broad range of less complex goods. This approach can produce counterintuitive results, as seen in the treatment of raw materials. Products such as oil may appear complex when exported by high-ECI countries, which in turn skews the rankings of nations that rely heavily on resource exports (Tacchella et al. 2019).

Another major concern is the potential oversimplification inherent in the ECI framework. By reducing economic complexity to a set of mathematical calculations, the index may obscure important socio-economic variables and country-specific contexts. It often fails to capture nuanced structural factors, including the role of intermediate goods and participation in global value chains, which are critical in understanding modern production networks (Kummritz, 2016).

Furthermore, the ECI's reliance on the concepts of capabilities and knowledge has been questioned, particularly due to the lack of precise definitions and measurable indicators for these terms. As a result, the assumed link between economic complexity and economic growth is not always straightforward. Given these limitations, the ECI is frequently used as a descriptive analytical tool rather than a direct policy instrument for development planning (Bandeira Morais, 2023).

2.3. Previous Studies on Human Development and Economic Complexity

Several studies have explored the relationship between these two concepts. One notable example is Lapatinas' (2016) "Economic complexity and human development: a note." This study examines the evolution of both indicators (ECI and HDI) from 1965 to 2005 using data from 126 countries. It utilized panel data to determine whether changes in ECI values impact HDI values, represented by the following equation:

$$HDI_{it} = \alpha HDI_{it-1} + \gamma ECI_{it-1} + \delta_i + \mu_t + \varepsilon_{it}$$

The human development index HDI_{it} represents country i in period t. The lagged value of this variable on the right-hand side is included to capture persistence in human development. The variable ECI_{it-1} represents the lagged value of the economic complexity index. The parameter γ measures the effect of economic complexity on human development. The δ's denote a complete set of country dummies, and the μ_t's denote a complete set of time effects that capture standard shocks to the HDI of all countries. ε_{it} is the error term. The study did not reveal any significant relationship between economic complexity and human development indicators over the analyzed period, as economic complexity was not identified as a determinant of human development. Several possible reasons for these findings have been proposed, such as the increase in social choices brought by increased economic complexity, which can create both positive and negative effects on human development that ultimately cancel each other out. Despite this finding, there remains a possibility that the two indicators are related, and the time duration of the study may be too long to capture how economic complexity impacts human development (Lapatinas, 2016). It should be noted that this study was more related to the ECI having an effect on the variation in the HDI, which is in a certain way opposite to what we might tend to expect, since countries with higher human development already have a higher ECI, which means their variation is going to be lower.

In a study by Soyyigit (2019), the relationship between economic complexity and human development was investigated in G20 countries using panel cointegration analysis covering 1997-2017. The findings reveal a long-term relationship between HDI and ECI when ECI is the dependent variable and HDI is the independent variable. However, when the variables switch roles, this relationship does not hold. Interestingly, HDI affected ECI for all G20 countries except the United States, showing negative impacts in developed countries and positive impacts in developing nations (Soyyigit, 2019).It is important to note that this study examined the opposite causal direction from the current research, Soyyigit found the effect of HDI on ECI, while this study examines the effect of ECI on HDI.

3. Methodology

This study explores whether a country's level of human development, as measured by the Human Development Index (HDI), can be influenced by its level of economic complexity, as captured by the Economic Complexity Index (ECI). The main question guiding this analysis is whether higher or lower ECI scores are linked to meaningful differences in HDI.

To investigate this, the analysis includes all 127 countries for which ECI, HDI, and GDP per capita data are available for the year 2023 (see table VI), the most recent year with complete data from the ECI, which is one of the three indicators with the least available data. The specific countries can be found in (table IV). The data used in this investigation originates from three different databases: the ECI is taken from the Observatory of Economic Complexity related to trade, as it is the source with the most information as well as the original and most widely used ECI data (OEC, 2024) .For the HDI, data from the Human Development Report of 2023, which is created by the UN, was used (UNDP,2024) . For GDP per capita, which has the most potential data sources, it was decided to use data from the World Bank, using current US dollars as the value (World Bank, 2024) .

Focusing on a single year allows for a clearer view of the relationship between ECI and HDI without the added complexity of changes over time. Previous studies that examined extended periods often reported mixed or inconsistent results. By narrowing the scope, this study aims to offer a more direct understanding of how ECI might be connected to HDI outcomes.

The first step will be a Pearson correlation, which will enable us to determine if there is a simple correlation between the ECI and the HDI. This will be the foundation of the work, as the remaining steps are based on the assumption that there is a correlation between the two indicators.

A key part of this approach involves minimizing the influence of GDP, a shared component in both indices that may distort the actual connection between them. Since GDP often dominates such relationships, controlling for it will help reveal whether economic complexity itself (pure ECI), not just overall income, is related to improvements in human development. For this the Regression residuals of the ECI and GDP per capita relation will be used.

Countries will be grouped based on their HDI values into higher and lower development categories. This will help highlight whether economic complexity without the effect of GDP per capita has a stronger or weaker association with human development at different ends of the HDI scale.

In this study it will also be investigated whether the relationship between the pure ECI and HDI varies across different stages of human development, as it is possible there is a difference based on development level itself. Specifically, we examine whether this relationship strengthens, weakens, or disappears entirely at human development thresholds, and if so, at what HDI levels these changes occur. To address this question, countries will be categorized into the four HDI development tiers (low, medium, high, and very high) to determine at which development stage economic complexity ceases to significantly influence human development outcomes.

The outliers in the relationship between the ECI and HDI will also be examined and analyzed. These regression outliers will be used to explain the correlation. The regression with GDP per capita will be used instead of regression without GDP per capita. The countries used for this analysis were those where the difference between the HDI predicted by the ECI and the actual HDI was at least 0.2.

In the regressions where there is no mention of p-value in the data analysis, the value of it is inferior to 0,01.

4. Data Analysis

The first step involves a Pearson correlation analysis to examine the relationship between ECI as the independent variable and HDI as the dependent variable, yielding the following model:

HDI = 0.758389 + 0.126355(ECI)

Table I. HDI as dependent variable and ECI as independent variable regression

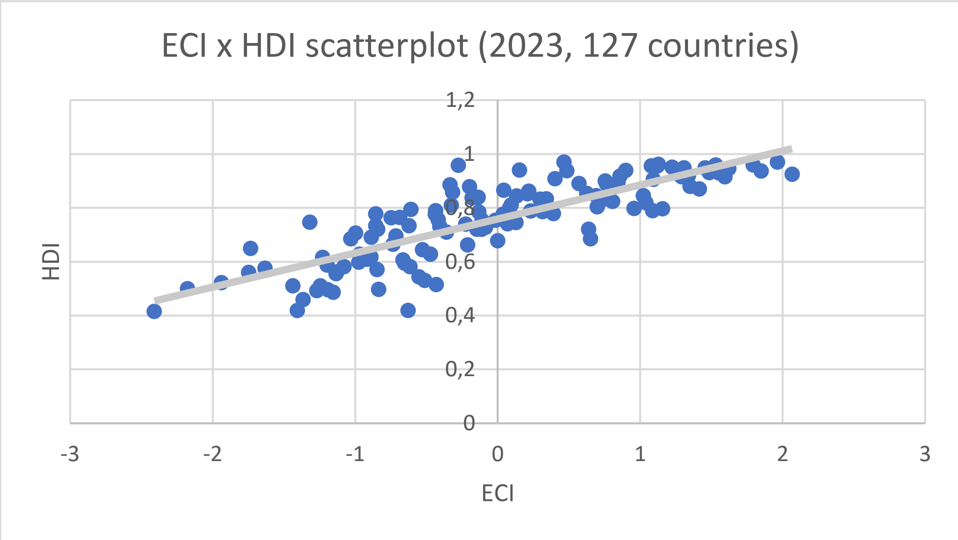
Regression Statistics	
Multiple R	0,837758
R Square	0,701838
Adjusted R Square	0,699453
Standard Error	0,082351
Observations	127

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1,995423	1,995423	294,2355	1,21E-34
Residual	125	0,847715	0,006782		
Total	126	2,843138			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,758389	0,007307	103,7824	3,8E-123	0,743927	0,772852
X Variable 1	0,126355	0,007366	17,1533	1,21E-34	0,111777	0,140934

This reveals a strong correlation between ECI and HDI, with a correlation coefficient of 0.838, indicating a clear and consistent relationship between these two indices (see table I). The R value of 0.702 indicates that ECI explains a significant portion (70.2%) of the variance in HDI. This supports the base hypothesis that higher ECI values have a strong positive impact on HDI values. This relationship is visualized in Graph 1.



Graph 1:

ECI x HDI scatterplot (2023, 127 countries).

Sources: ECI data [1]; HDI data [2]

The graph demonstrates that increases in ECI and HDI are correlated: countries with the highest ECI values also tend to have greater HDI scores, and this correlation is similarly observed among countries with lower ECI and HDI values.

The second step examines the relationship using all three indicators, investigating what differences exist when HDI serves as the dependent variable and both ECI and GDP per capita serve as independent variables – i.e., when we control for the effect of GDPpc in order to ascertain whether economic complexity has an effect on human development above and beyond being associated with a higher income per capita. The following multiple regression model was estimated:

HDI = 0.69016 + 0.07958(ECI) + 0.02281(GDP per capita)

Table II. HDI dependent variable regression with ECI and GDP as independent variables regression

Regression Statistics	
Multiple R	0,889998
R Square	0,792097
Adjusted R Square	0,788744
Standard Error	0,069043
Observations	127

ANOVA

	df	SS	MS	F	Significance F
Regression	2	2,25204	1,12602	236,2157	5,1E-43
Residual	124	0,591097	0,004767		
Total	126	2,843138			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0,690157	0,011136	61,97388	3,66E-95	0,668116	0,712199
ECI	0,079582	0,008876	8,966113	3,94E-15	0,062014	0,09715
GDP per capita/10000	0,022808	0,003109	7,3371	2,5E-11	0,016655	0,028961

Table III. ECI as dependent variable and GDP per capita as independent variable

Regression Statistics	
Multiple R	0,718234
R Square	0,515861
Adjusted R Square	0,511987
Standard Error	0,695752
Observations	127

ANOVA

	df	SS	MS	F	Significance F
Regression	1	64,47341	64,47341	133,1901	2,01E-21
Residual	125	60,50884	0,484071		
Total	126	124,9822			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0,75317	0,089753	-8,39159	8,71E-14	-0,9308	-0,57554
GDP per capita/10000	0,251545	0,021796	11,5408	2,01E-21	0,208408	0,294682

With an R-squared of 0.792, this model explains approximately 79.2% of the variation in HDI, and the overall model is statistically significant ($p < 0.001$) (see table II). This result indicates a stronger combined effect from ECI and GDP than from ECI alone on HDI. However, the data suggests a potential multicollinearity problem between ECI and GDP. This possibility stems from the strong correlation between ECI and GDP per capita (r = 0.718) (see table III), indicating the presence of multicollinearity. This multicollinearity causes ECI and GDP per capita to compete in explaining the same variance in HDI, leading to unstable coefficient estimates.

To address this issue, separate regression models were estimated with HDI as the dependent variable and each indicator as an individual independent variable:

HDI = 0,63022 + 0,04283(GDP per capita)

Table IV. HDI as dependent variable and GDP per capita as independent variable regression

Regression Statistics	
Multiple R	0,810746
R Square	0,65731
Adjusted R Square	0,654568
Standard Error	0,088287
Observations	127

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1,868823	1,868823	239,761	7,47E-31
Residual	125	0,974315	0,007795		
Total	126	2,843138			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,630219	0,011389	55,33554	9,05E-90	0,607679	0,652759
X Variable 1	0,042826	0,002766	15,48422	7,47E-31	0,037352	0,0483

The results show an R-square of 0.657 for the GDP-only model (see table IV) and 0.702 for the ECI-only model (Table I). This indicates that ECI has stronger explanatory power for HDI variation than GDP per capita alone, consistent with the findings from the multiple regression analysis.

To further isolate the effect of ECI from GDP influence, a residual analysis approach was employed (Wooldridge, 2020). This involved regressing ECI on GDP per capita to obtain an ECI measure purged of GDP effects. The residuals from this regression represent the component of ECI that is independent of GDP per capita, allowing for a cleaner assessment of ECI's unique impact on HDI.

After removing multicollinearity by excluding GDP effects from ECI, we found an R-squared of 0.515, indicating that GDP alone explains approximately 51.5% of ECI's variation. We also found a R of 0.718, implying a strong correlation between ECI and GDP per capita. This supports the multicollinearity hypothesis due to the strong correlation value (see table III).

Subsequently, HDI was regressed against the GDP-adjusted ECI (see table VIII), yielding a R of 0.367 and a modest R-squared of 0.135. This suggests that most of ECI's impact on HDI operates through GDP, while its independent effect is relatively small, both in proportion to ECI's overall effect and compared to GDP's direct impact. Nevertheless, a meaningful positive independent effect of ECI on HDI remains(see table IX).

Now that the general assessment of ECI's importance for HDI is complete, we must determine whether ECI's impact on HDI differs depending on the country's development level. For this analysis, countries were split into high and very high development countries versus medium and low development countries to examine any changes in the effects of residual ECI (without GDP) on HDI values.

From this split between high/very high HDI countries and medium/low HDI countries, using the ECI residuals, we find a significant difference in ECI's effect on both groups. In the group of lower and medium HDI countries, the R is 0.41 while the R-squared of the ECI residual (after removing the GDP effect) on HDI is 0.168. This indicates that the ECI residual has a moderately weak but existing correlation and meaningful effect on HDI for this group of countries, despite being relatively small (see table X). Conversely, when examining countries with high and very high HDI, the R-squared was nearly zero at 0.0002 and the p-value of 0,88. This means that for these countries, ECI without the effect of GDP has no meaningful impact on their development level (see table XI).

After that first split between the upper and lower HDI countries, the four tiers used by the United Nations development reports, of the HDI were used to determine where the pure ECI has a greater effect, as it is possible that only the most developed countries show no effect of the ECI on the HDI. The split was made at HDI equal to 0.55 for the low developed countries, then at 0.7 for the medium-developed countries, 0.8 for the highly developed countries, and above those were the very highly developed countries.

The results of these tests were similar to the previous ones. The most developed countries, those in the very high HDI category, had an R-squared value of 0.013, very close to zero and a p value of 0,41, meaning there is no relation between the variables for those countries (see table XII). The R-square of the highly developed countries was slightly higher, having a value of 0.077 and a p-value of 0,11 (see table XIII). This means there is no relation between the variables in both these cases.

The medium developed countries were the ones where the pure ECI had the biggest explanatory power, with the R-squared being 0.184 and a p-value of 0,036. This means the correlation coefficient between the ECI and HDI, despite being small, reaches its highest value with these countries (see table XIV). For the countries with lower HDI, the R-squared of this relation is only 0.086 and a p-value of 0,27, similar to the highly developed countries. Meaning there is no relation between variables in this tier (see table XV).

After those results determined that the highest developed countries were the ones where there was not a significant relation between the pure ECI and the HDI, it was tested whether the remaining countries had a better relation when all were placed in a regression with this form of ECI. The result was an R-squared of 0.306. This was the result where the relation between the pure ECI and the HDI was strongest, meaning there is a relation that, despite not explaining all the variation of the HDI, could explain almost one-third of it (see table V).

Table V. HDI as dependent variable pure ECI as independent variable regression for low medium and high HDI countries

Regression Statistics	
Multiple R	0,552994
R Square	0,305802
Adjusted R Square	0,296024

Standard Error	0,093322
Observations	73

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0,272387	0,272387	31,27628	3,91E-07
Residual	71	0,618343	0,008709		
Total	72	0,89073			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0,668619	0,011181	59,79843	1,78E-62	0,646324	0,690914
X Variable 1	0,100838	0,018031	5,59252	3,91E-07	0,064886	0,136791

Regarding outliers in the relationship between ECI and HDI, the two most significant are Niger and Australia, as those are the two only with a variation of more than 0,2 between the predicted HDI by the ECI and the actual HDI (see table VIII). Niger has an actual HDI of 0.419, which is 0.26 points lower than the predicted value of 0.679 based on the regression of ECI values for this country. In contrast, Australia's ECI-based regression would have predicted an HDI value of 0.723, while the actual HDI is approximately 0.958, representing a difference of 0.234 points.

5. Discussion

This analysis used data from 2023 and included 127 countries (see table VI).

From the first step, a relationship between ECI and HDI was revealed, with the former having a significant impact on the latter. The first step demonstrated that a relationship exists between the two indices and that a substantial portion of HDI can be estimated based on ECI changes. This established the expected result of ECI having an impact on HDI, with a strong overall correlation between ECI and HDI (r = 0.838) and good explanatory power for HDI changes (R-squared = 0.702), demonstrating that these indices capture related aspects of national development.

The second step involved including GDP in the regression. In this step, we found that ECI still had a greater effect than GDP on HDI, as a variation of 1 in ECI resulted in a 0.079 increase in HDI, which is substantial for an index ranging from 0 to 1. For GDP, a change of one unit (representing $10,000 in this case) only impacts HDI by 0.0228 points. However, questions remained about potential multicollinearity between ECI and GDP per capita. Additional regressions with HDI as the dependent variable yielded similar findings, with an R-square of 0.657, which is lower than the 0.702 value found in the regression using only ECI and HDI. This means that for both cases the ECI has more effect on the HDI than GDPpc alone.

An examination of GDP's impact on ECI was then conducted to determine how much of ECI could be explained by GDP. This revealed significant multicollinearity between ECI and GDP per capita ($r = 0.718$), helping explain why previous studies produced mixed results. Much of what appears to be an ECI effect on HDI actually operates through income channels, accounting for approximately 51.5% of ECI's explanatory power.

The third step involved removing GDP's residual effects on ECI, allowing us to measure ECI's impact on HDI without GDP interference. We found a relationship between ECI and HDI even without GDP interference, with an R-squared of 0.1305. Although small, this represents a real relationship between ECI and HDI when GDP effects are removed.

The final step involved splitting results between high/very high development countries and low/medium development countries to identify differences between them. The results reveal that economic complexity influences human development more in countries with lower human development, explaining 16.8% of their variation when removing GDP effects, while in more developed countries it has virtually no effect.

More importantly, when we isolate the GDP-independent effect of ECI, we find a striking pattern, economic complexity matters substantially for human development in lower and medium HDI countries (explaining 16.8% of HDI variation) but has virtually no impact in high and very high HDI countries (explaining only 0.02% of variation and having a p-value of 0,88). This differential effect suggests that the relationship between complexity and development is not universal but rather depends critically on a country's stage of development.

When splitting the data of the regression using the pure ECI effect across the four different tiers of HDI, the results were different from those reached previously. For all tiers except the medium tier, the p-values indicated values greater than 0.1, which means there is no statistical significance in those regressions. For the medium HDI countries, the relationship is clearly the strongest, as the pure ECI can explain around 18% of the variance. This represents a clearly greater explanatory power than the values obtained in all the regressions made previously using pure ECI.

While conducting this research, as the clear outlier was the very highly developed group of countries, a regression was tested with all the countries except those in the very highly developed group. When doing this with the pure ECI, the variation explained by it was 30%. This means that, excluding GDP from the relation, the variation of HDI explained by the ECI was around one-third of the variation in HDI. This value is the highest of all the results, as the ECI better explains the HDI in countries without very high levels of development when all are aggregated.

Several factors explain why economic complexity has a stronger impact on human development in less developed countries. First, the ECI calculation method focuses exclusively on products rather than services, meaning it better captures the economic reality of countries where manufacturing and primary production dominate. As countries develop, services become increasingly important, but these are not reflected in goods-based complexity measures.

Second, the recursive nature of ECI calculation means that complexity "flows from top to bottom" - more complex countries tend to produce more complex products, which in turn define them as complex. Within this hierarchy, developing countries that manage to produce relatively more complex products gain a development advantage over those producing simpler goods. This advantage manifests in several ways: complex production requires more skilled labor, driving human capital development; sophisticated production networks demand better institutions and governance; and diversified economies are more resilient to external shocks. However, these benefits exhibit diminishing returns - they are most pronounced when countries start from lower development baselines. For developing countries, gaining economic complexity represents a fundamental structural transformation that drives substantial improvements in institutions, human capital, and economic resilience. In contrast, developed countries have already undergone this transformation, so additional complexity gains yield smaller marginal improvements in human development, as other factors beyond manufacturing complexity become more important for further progress. This explains why the ECI-development relationship is stronger in lower IDH countries.

Third, for less developed countries, the marginal benefits of productive diversification are likely higher. Moving from simple to moderately complex production can yield substantial improvements in skills, institutions, and economic resilience. In contrast, advanced economies may experience diminishing returns from additional complexity, particularly as their development depends increasingly on intangible factors like innovation, service quality, and institutional sophistication that are not captured by goods-based complexity measures.

Regarding the most significant outliers, they exist for opposite reasons and represent opposite types of differences. In Niger's case, ECI would predict a higher HDI than observed. In Australia's case, ECI predicts an HDI much lower than the actual value. For Australia, more than two-thirds of its exports are mineral products like iron ore, coal briquettes, and petroleum gas, averaging an economic complexity of negative 2 among those 3 products. This creates an effect that lowers the country's complexity score due to these products' weight. In Niger's case, the situation differs. Niger ranks third lowest in HDI among the countries in our dataset, yet its ECI, while in the lower half of the list, remains higher than countries at the bottom. This can be explained by the diversification of its industry: while relying heavily on gold, vegetable products, and mineral products, it maintains small but existing production of machines and transportation equipment, bringing the ECI to a higher value than expected for a country with such low development.

These findings have important policy implications that vary according to development level. For developing countries, the results support industrial policies focused on productive diversification and complexity upgrading. The 30% of HDI variation explained by ECI residuals suggests that investments in more sophisticated production capabilities can yield meaningful development benefits beyond simple income generation. Countries should focus on identifying products with high "relatedness" to their existing capabilities - products requiring similar skills and institutions but offering higher complexity.

For developed countries, the absence of meaningful ECI effects suggests that traditional industrial policy focused on manufacturing complexity may be less relevant. Instead, these countries should focus on service sector development, innovation systems, and institutional quality improvements not captured by current complexity measures.

Examining previous studies on the relationship between human development and economic complexity, we find possible reasons why both Lapatinas (2016) and Soyyigit (2019) obtained mixed results. One possible factor for different research results is structural changes the global economy has undergone. With the growth of global production chains, complexity levels and their relationships with human development have shifted. Despite this, Soyyigit's (2019) findings about effects for G20 countries align with our research, as there is no clear relationship between the human development of the most developed countries and their complexity level after controlling for the effect of GDP per capita.

6. Limitations

Our analysis has several limitations that should be acknowledged. The cross-sectional design limits our ability to make causal inferences about the relationship's direction between the two indices. The ECI's focus on goods exports may understate both domestic production in producing countries and the complexity of service-oriented economies, potentially explaining why we find no effects in developed countries. Additionally, our single-year analysis, while methodologically advantageous for eliminating temporal confounding, may not capture the dynamic nature of the complexity-development relationship.

Future research should develop complex measures that better capture service sector sophistication and identify the specific industries where development is most significantly impacted by economic complexity. Another important research direction would be to identify the precise threshold points where the effect of ECI on HDI changes, without relying on predetermined HDI categories.

7. Conclusion

Several conclusions can be drawn from this work relating to human development measured by HDI and industrial development measured by economic complexity using ECI. A relationship exists between the two indices, demonstrated by both high correlation and the regression with HDI as the dependent variable and ECI as independent variable showing high explanatory value. In the multiple regression phase, findings remained consistent with a slight increase in correlation and explanatory factor for HDI. ECI and GDP variables with HDI as the dependent variable, the R-squared value increases, meaning both have an effect on HDI. However, much of ECI's interference in HDI can be isolated through GDP changes. This is certainly interesting but not the main focus of this work.

A relationship was expected as there are areas where both indices analyze similar enough data beyond only wealth, as the ECI analyzes, in a certain way, the know-how while education is one of the principal factors in the HDI. Although those two factors, one for each index, are not the same, they theoretically have a tendency to move in the same direction. The questions asked in the introduction are answered as there is a relationship between the complexity of a country and its human development, as well as the fact that this relationship tends to be independent of the wealth of countries, in countries where human development is not very high.

Multiple reasons exist for these results. From the outset, ECI is based on manufactured products, meaning services, which predominate in the most developed countries, do not show as strong a relationship with ECI and HDI. Another possible reason for the difference is the "flow from top to bottom" of complexity, meaning complex countries are already the most developed. This makes ECI's impact on HDI nonexistent for them, while for countries with less development, having a more complex economy can be an important factor in achieving greater development. Finally, there are larger marginal increases in developing countries than in developed ones.

The main limitations of the study relate to the fact that ECI is calculated using trade rather than production directly. There is also the issue of using only one year of data, which creates the possibility that the results may not be reliable.

Despite these findings, this work should not be seen as approaching the end of studying the relationship between these two indices; many questions remain to be answered. Does time affect this positive relationship between ECI and HDI in lower developed countries? In less developed countries, can ECI serve as a driver for making less developed countries more developed by itself?

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9. Appendices

Appendix 1 – Values of the variables used in regressions

Table VI. List of countries, values of ECI, HDI and GDP per capita (divided by 10,000 for better comparation)

Country	HDI	ECI	GDP per capita/10000
Chad	0,416	-2,409167	0,186394062
Mali	0,419	-1,406481	0,265771298
Niger	0,419	-0,629219	0,189050519
Burkina Faso	0,459	-1,36443	0,275471347
Madagascar	0,487	-1,153308	0,182381733
Mozambique	0,493	-1,269232	0,167768102
Afghanistan	0,496	-1,19327	0,221128063
Ethiopia	0,497	-0,835691	0,305812804
Guinea	0,5	-2,175925	0,43831522
Liberia	0,51	-1,436257	0,179453341
Sudan	0,511	-1,243427	0,274042114
Benin	0,515	-0,431494	0,412997941
Democratic Republic of the Congo	0,522	-1,937605	0,161575071
Senegal	0,53	-0,511599	0,479144862
Pakistan	0,544	-0,55325	0,603665077
Tanzania	0,555	-1,134971	0,40185166
Nigeria	0,56	-1,748188	0,620742138
Mauritania	0,563	-1,128063	0,694619393
Togo	0,571	-0,845866	0,307151217
Papua New Guinea	0,576	-1,632804	0,463297979
Côte d'Ivoire	0,582	-1,079027	0,71976901
Uganda	0,582	-0,615716	0,309763702
Cameroon	0,588	-1,19706	0,540557466
Zambia	0,595	-0,652758	0,407699509
Zimbabwe	0,598	-0,975336	0,382036263
Cambodia	0,606	-0,664874	0,742551179
Myanmar	0,609	-0,913441	0,595335735
Angola	0,616	-1,229129	0,804070245
Laos	0,617	-0,889136	0,929178859
Ghana	0,628	-0,968259	0,754302675
Kenya	0,628	-0,471124	0,630723249
Honduras	0,645	-0,526682	0,717880729
Republic of the Congo	0,649	-1,734017	0,685027771
Guatemala	0,662	-0,209816	1,375028791
Namibia	0,665	-0,735228	1,121554684
El Salvador	0,678	0,0011772	1,265703406
Bangladesh	0,685	-1,02998	0,914777751
India	0,685	0,6525508	1,016624341
Tajikistan	0,691	-0,887902	0,496358295
Iraq	0,695	-0,71379	1,410729793
Nicaragua	0,706	-0,996342	0,830933991
Morocco	0,71	-0,359139	0,984288867
Jamaica	0,72	-0,144593	1,142175356

Kyrgyzstan	0,72	-0,111661	0,710649114
Philippines	0,72	0,6376833	1,098863004
Libya	0,721	-0,84185	1,3848795
Indonesia	0,728	-0,085367	1,541560579
Botswana	0,731	-0,406697	2,091640155
Bolivia	0,733	-0,854921	1,092527305
Gabon	0,733	-0,622306	2,075707238
Uzbekistan	0,74	-0,224777	1,110697159
South Africa	0,741	0,0699776	1,519419918
Tunisia	0,746	0,1292216	1,393185932
Mongolia	0,747	-1,317606	1,800485121
Egypt	0,754	-0,109192	1,852455722
Jordan	0,754	-0,015473	1,039101361
Paraguay	0,756	-0,418461	1,751679847
Algeria	0,763	-0,747599	1,68244879
Turkmenistan	0,764	-0,687694	1,982892485
Vietnam	0,766	0,0670963	1,497388396
Dominican Republic	0,776	0,03957	2,562400977
Sri Lanka	0,776	-0,438505	1,446074142
Ecuador	0,777	-0,854889	1,606201636
Ukraine	0,779	0,3914417	1,7630125
Moldova	0,785	-0,131912	1,759688342
Brazil	0,786	0,3140861	2,11072821
Colombia	0,788	0,2323878	2,078449964
Azerbaijan	0,789	-0,434803	2,359783786
Mexico	0,789	1,0872195	2,47896756
Peru	0,794	-0,608976	1,6974242
China	0,797	1,1566898	2,456928651
Thailand	0,798	0,9573769	2,346506314
Iran	0,799	0,0843932	1,765987393
Bosnia and Herzegovina	0,804	0,6985166	2,24491503
Albania	0,81	-0,326465	2,126319566
Armenia	0,811	0,0937887	2,134251453
Malaysia	0,819	1,0396369	3,641654019
Belarus	0,824	0,8056959	3,076301982
Russia	0,832	0,2977254	4,412014453
Costa Rica	0,833	0,3419472	2,807514217
Serbia	0,833	0,7624829	2,874847596
Kazakhstan	0,837	-0,178969	3,85151836
Panama	0,839	-0,136149	3,980331895
Georgia	0,844	0,132188	2,507196771
Bulgaria	0,845	0,6913365	3,75077734
Romania	0,845	1,0232497	4,577703873
Kuwait	0,852	0,2100797	5,156136381
Türkiye	0,853	0,624347	4,232616444
Oman	0,858	-0,316568	4,251970499
Uruguay	0,862	0,2174597	3,442660247
Argentina	0,865	0,0426325	3,008230452
Hungary	0,87	1,4149483	4,5021301

Chile	0,878	-0,196877	3,280287222
Slovakia	0,88	1,3502696	4,362536419
Qatar	0,886	-0,334858	12,89185493
Croatia	0,889	0,7639503	4,560296011
Portugal	0,89	0,5704845	4,73310983
Lithuania	0,895	0,8454093	5,091486381
Saudi Arabia	0,9	0,7551051	6,110291537
Poland	0,906	1,0915777	4,657047027
Greece	0,908	0,4018323	4,118199122
Czechia	0,915	1,5954823	5,321742174
Italy	0,915	1,2911329	5,780136626
Spain	0,918	0,858127	5,322992202
Israel	0,919	1,2843427	5,405704841
France	0,92	1,339835	5,831782803
Japan	0,925	2,067091	4,979393582
Austria	0,93	1,5551126	7,047878736
Slovenia	0,931	1,4843008	5,395220473
South Korea	0,937	1,8491088	5,220396857
New Zealand	0,938	0,4849325	5,344013101
United States	0,938	1,4985359	8,276941221
Canada	0,939	0,8980337	6,352470387
United Arab Emirates	0,94	0,1520339	7,611038485
Singapore	0,946	1,6213788	14,1553473
United Kingdom	0,946	1,4973891	5,822513116
Finland	0,948	1,4561984	6,173445981
Ireland	0,949	1,3069071	12,49009386
Belgium	0,951	1,2254345	6,907283339
Hong Kong	0,955	1,1208218	7,15489642
Netherlands	0,955	1,0791804	7,830528884
Australia	0,958	-0,275804	7,049715245
Germany	0,959	1,7922192	6,920588307
Sweden	0,959	1,5308165	6,719802004
Denmark	0,962	1,1286343	7,373744754
Norway	0,97	0,465563	10,09283546
Switzerland	0,97	1,9643179	8,954627849

Appendix 2 – Values of the of the residuals of the ECI used in regressions

Table VII. Residuals of ECI

Observation	*Predicted ECI*	*Residuals ECI*
Chad	-0,70628	-1,70289
Mali	-0,68631	-0,72017
Niger	-0,70561	0,076393
Burkina Faso	-0,68387	-0,68056
Madagascar	-0,70729	-0,44602
Mozambique	-0,71097	-0,55827
Afghanistan	-0,69754	-0,49573

Ethiopia	-0,67624	-0,15945
Guinea	-0,64291	-1,53301
Liberia	-0,70803	-0,72823
Sudan	-0,68423	-0,55919
Benin	-0,64928	0,217786
Democratic Republic of the Congo	-0,71252	-1,22508
Senegal	-0,63264	0,121041
Pakistan	-0,60132	0,048068
Tanzania	-0,65208	-0,48289
Nigeria	-0,59702	-1,15117
Mauritania	-0,57844	-0,54962
Togo	-0,6759	-0,16996
Papua New Guinea	-0,63663	-0,99618
Côte d'Ivoire	-0,57211	-0,50691
Uganda	-0,67525	0,059532
Cameroon	-0,61719	-0,57987
Zambia	-0,65061	-0,00215
Zimbabwe	-0,65707	-0,31827
Cambodia	-0,56638	-0,09849
Myanmar	-0,60341	-0,31003
Angola	-0,55091	-0,67822
Laos	-0,51944	-0,3697
Ghana	-0,56343	-0,40483
Kenya	-0,59451	0,123387
Honduras	-0,57259	0,045906
Republic of the Congo	-0,58085	-1,15317
Guatemala	-0,40729	0,197469
Namibia	-0,47105	-0,26418
El Salvador	-0,43479	0,435963
Bangladesh	-0,52306	-0,50692
India	-0,49744	1,149991
Tajikistan	-0,62831	-0,25959
Iraq	-0,3983	-0,31548
Nicaragua	-0,54415	-0,45219
Morocco	-0,50557	0,146435
Jamaica	-0,46586	0,321265
Kyrgyzstan	-0,57441	0,462746
Philippines	-0,47675	1,114437
Libya	-0,40481	-0,43704
Indonesia	-0,36539	0,280027
Botswana	-0,22703	-0,17967
Bolivia	-0,47835	-0,37657
Gabon	-0,23103	-0,39127
Uzbekistan	-0,47378	0,249
South Africa	-0,37096	0,440942
Tunisia	-0,40272	0,53194
Mongolia	-0,30026	-1,01734
Egypt	-0,28719	0,177999

Jordan	-0,49179	0,476313
Paraguay	-0,31254	-0,10592
Algeria	-0,32996	-0,41764
Turkmenistan	-0,25438	-0,43331
Vietnam	-0,37651	0,443603
Dominican Republic	-0,10861	0,148178
Sri Lanka	-0,38941	-0,04909
Ecuador	-0,34913	-0,50575
Ukraine	-0,30969	0,701132
Moldova	-0,31053	0,178614
Brazil	-0,22222	0,53631
Colombia	-0,23034	0,462731
Azerbaijan	-0,15957	-0,27523
Mexico	-0,12959	1,216814
Peru	-0,32619	-0,28279
China	-0,13514	1,291828
Thailand	-0,16291	1,120292
Iran	-0,30894	0,393335
Bosnia and Herzegovina	-0,18847	0,886986
Albania	-0,2183	-0,10816
Armenia	-0,21631	0,310095
Malaysia	0,162873	0,876764
Belarus	0,020662	0,785034
Russia	0,356654	-0,05893
Costa Rica	-0,04695	0,388898
Serbia	-0,03001	0,792496
Kazakhstan	0,215664	-0,39463
Panama	0,248066	-0,38422
Georgia	-0,12249	0,254682
Bulgaria	0,190323	0,501014
Romania	0,398332	0,624918
Kuwait	0,543834	-0,33375
Türkiye	0,311527	0,31282
Oman	0,316395	-0,63296
Uruguay	0,112817	0,104642
Argentina	0,003539	0,039094
Hungary	0,379322	1,035626
Chile	0,071973	-0,26885
Slovakia	0,344208	1,006062
Qatar	2,489716	-2,82457
Croatia	0,393953	0,369997
Portugal	0,437424	0,133061
Lithuania	0,527572	0,317838
Saudi Arabia	0,783847	-0,02874
Poland	0,418291	0,673287
Greece	0,282746	0,119086
Czechia	0,585491	1,009991
Italy	0,700798	0,590335
Spain	0,585806	0,272321

Israel	0,606612	0,677731
France	0,71379	0,626045
Japan	0,499375	1,567716
Austria	1,019693	0,53542
Slovenia	0,603974	0,880326
South Korea	0,559998	1,28911
New Zealand	0,591094	-0,10616
United States	1,328857	0,169679
Canada	0,844766	0,053268
United Arab Emirates	1,161353	-1,00932
Singapore	2,807542	-1,18616
United Kingdom	0,711458	0,785931
Finland	0,799733	0,656465
Ireland	2,388655	-1,08175
Belgium	0,984327	0,241108
Hong Kong	1,046612	0,074209
Netherlands	1,216564	-0,13738
Australia	1,020155	-1,29596
Germany	0,987673	0,804546
Sweden	0,937167	0,59365
Denmark	1,101663	0,026972
Norway	1,785637	-1,32007
Switzerland	1,499326	0,464992

Appendix 3 – Values of the of the residuals of the HD used to find the outliers

Table VIII. Residuals from the regression with HDI as dependent variable and ECI as dependent variable

Observation	*Predicted HDI*	*Residuals*
Chad	0,453978	-0,03798
Mali	0,580673	-0,16167
Niger	0,678884	-0,25988
Burkina Faso	0,585986	-0,12699
Madagascar	0,612663	-0,12566
Mozambique	0,598015	-0,10501
Afghanistan	0,607613	-0,11161
Ethiopia	0,652795	-0,1558
Guinea	0,48345	0,01655
Liberia	0,57691	-0,06691
Sudan	0,601276	-0,09028
Benin	0,703868	-0,18887
Democratic Republic of the Congo	0,513563	0,008437
Senegal	0,693746	-0,16375
Pakistan	0,688483	-0,14448
Tanzania	0,61498	-0,05998
Nigeria	0,537496	0,022504

Mauritania	0,615852	-0,05285
Togo	0,651509	-0,08051
Papua New Guinea	0,552076	0,023924
Côte d'Ivoire	0,622048	-0,04005
Uganda	0,68059	-0,09859
Cameroon	0,607134	-0,01913
Zambia	0,67591	-0,08091
Zimbabwe	0,63515	-0,03715
Cambodia	0,674379	-0,06838
Myanmar	0,642971	-0,03397
Angola	0,603082	0,012918
Laos	0,646042	-0,02904
Ghana	0,636045	-0,00804
Kenya	0,69886	-0,07086
Honduras	0,69184	-0,04684
Republic of the Congo	0,539287	0,109713
Guatemala	0,731878	-0,06988
Namibia	0,665489	-0,00049
El Salvador	0,758538	-0,08054
Bangladesh	0,628246	0,056754
India	0,840842	-0,15584
Tajikistan	0,646198	0,044802
Iraq	0,668198	0,026802
Nicaragua	0,632496	0,073504
Morocco	0,71301	-0,00301
Jamaica	0,740119	-0,02012
Kyrgyzstan	0,74428	-0,02428
Philippines	0,838964	-0,11896
Libya	0,652017	0,068983
Indonesia	0,747602	-0,0196
Botswana	0,707001	0,023999
Bolivia	0,650365	0,082635
Gabon	0,679758	0,053242
Uzbekistan	0,729987	0,010013
South Africa	0,767231	-0,02623
Tunisia	0,774717	-0,02872
Mongolia	0,591903	0,155097
Egypt	0,744592	0,009408
Jordan	0,756434	-0,00243
Paraguay	0,705514	0,050486
Algeria	0,663926	0,099074
Turkmenistan	0,671495	0,092505
Vietnam	0,766867	-0,00087
Dominican Republic	0,763389	0,012611
Sri Lanka	0,702982	0,073018
Ecuador	0,650369	0,126631
Ukraine	0,80785	-0,02885
Moldova	0,741721	0,043279
Brazil	0,798076	-0,01208

Colombia	0,787753	0,000247
Azerbaijan	0,70345	0,08555
Mexico	0,895765	-0,10677
Peru	0,681442	0,112558
China	0,904543	-0,10754
Thailand	0,879359	-0,08136
Iran	0,769053	0,029947
Bosnia and Herzegovina	0,84665	-0,04265
Albania	0,717139	0,092861
Armenia	0,77024	0,04076
Malaysia	0,889753	-0,07075
Belarus	0,860193	-0,03619
Russia	0,796008	0,035992
Costa Rica	0,801596	0,031404
Serbia	0,854733	-0,02173
Kazakhstan	0,735775	0,101225
Panama	0,741186	0,097814
Georgia	0,775092	0,068908
Bulgaria	0,845743	-0,00074
Romania	0,887682	-0,04268
Kuwait	0,784934	0,067066
Türkiye	0,837279	0,015721
Oman	0,718389	0,139611
Uruguay	0,785866	0,076134
Argentina	0,763776	0,101224
Hungary	0,937175	-0,06718
Chile	0,733513	0,144487
Slovakia	0,929003	-0,049
Qatar	0,716078	0,169922
Croatia	0,854918	0,034082
Portugal	0,830473	0,059527
Lithuania	0,865211	0,029789
Saudi Arabia	0,853801	0,046199
Poland	0,896316	0,009684
Greece	0,809163	0,098837
Czechia	0,959987	-0,04499
Italy	0,921531	-0,00653
Spain	0,866818	0,051182
Israel	0,920673	-0,00167
France	0,927684	-0,00768
Japan	1,019577	-0,09458
Austria	0,954886	-0,02489
Slovenia	0,945938	-0,01494
South Korea	0,992034	-0,05503
New Zealand	0,819663	0,118337
United States	0,947737	-0,00974
Canada	0,87186	0,06714
United Arab Emirates	0,777599	0,162401
Singapore	0,963259	-0,01726

United Kingdom	0,947592	-0,00159
Finland	0,942387	0,005613
Ireland	0,923524	0,025476
Belgium	0,913229	0,037771
Hong Kong	0,900011	0,054989
Netherlands	0,894749	0,060251
Australia	0,72354	0,23446
Germany	0,984845	-0,02585
Sweden	0,951816	0,007184
Denmark	0,900998	0,061002
Norway	0,817215	0,152785
Switzerland	1,006591	-0,03659

Appendix 4- Regression with pure ECI

Table IX. HDI as dependent variable pure ECI as independent variable regression

Regression Statistics	
Multiple R	0,367133
R Square	0,134787
Adjusted R Square	0,127865
Standard Error	0,140283
Observations	127

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,383218	0,383218	19,47309	2,18E-05
Residual	125	2,45992	0,019679		
Total	126	2,843138			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,75822	0,012448	60,91046	8,52E-95	0,733584	0,782857
Residuals ECI	0,079582	0,018034	4,412832	2,18E-05	0,04389	0,115274

Appendix 5- Regression with pure ECI for low and medium HDI countries

Table X. HDI as dependent variable pure ECI as independent variable regression for low and medium HDI countries

Regression Statistics

Multiple R	0,409683
R Square	0,16784
Adjusted R Square	0,145941
Standard Error	0,07232
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,040085	0,040085	7,664306	0,008659
Residual	38	0,198745	0,00523		
Total	39	0,23883			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,594183	0,014136	42,03373	1,81E-33	0,565566	0,6228
Residuals ECI	0,059565	0,021516	2,768448	0,008659	0,016009	0,103121

Appendix 6- Regression with pure ECI for high and very high HDI countries

Table XI. HDI as dependent variable pure ECI as independent variable regression for high and very high HDI countries

Regression Statistics	
Multiple R	0,015995
R Square	0,000256
Adjusted R Square	-0,01151
Standard Error	0,081262
Observations	87

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,000144	0,000144	0,021753	0,883095
Residual	85	0,561303	0,006604		
Total	86	0,561447			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,844553	0,009003	93,81269	1,31E-87	0,826653	0,862452
X Variable 1	-0,00188	0,012769	-0,14749	0,883095	-0,02727	0,023506

Appendix 7- Regression with pure ECI for very high HDI countries

Table XII. HDI as dependent variable pure ECI as independent variable regression for very high HDI countries

Regression Statistics	
Multiple R	0,114411
R Square	0,01309
Adjusted R Square	-0,00589
Standard Error	0,050038
Observations	54

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,001727	0,001727	0,689706	0,410061
Residual	52	0,130196	0,002504		
Total	53	0,131923			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,89877	0,006999	128,4127	9,45E-67	0,884726	0,912815
X Variable 1	-0,0075	0,009031	-0,83049	0,410061	-0,02562	0,010621

Appendix 8- Regression with pure ECI for high HDI countries

Table XIII. HDI as dependent variable pure ECI as independent variable regression for high HDI countries

Regression Statistics	
Multiple R	0,277375
R Square	0,076937
Adjusted R Square	0,04716
Standard Error	0,028083
Observations	33

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,002038	0,002038	2,583828	0,118099
Residual	31	0,024448	0,000789		
Total	32	0,026486			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,75463	0,005134	146,9807	1,19E-45	0,744158	0,765101
X Variable 1	0,014423	0,008972	1,607429	0,118099	-0,00388	0,032722

Appendix 9- Regression with pure ECI for medium HDI countries

Table XIV. HDI as dependent variable pure ECI as independent variable regression for medium HDI countries

Regression Statistics	
Multiple R	0,429315
R Square	0,184311
Adjusted R Square	0,147234
Standard Error	0,04041
Observations	24

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,008118	0,008118	4,971068	0,0363
Residual	22	0,035926	0,001633		
Total	23	0,044044			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,63426	0,009464	67,02026	6,22E-27	0,614633	0,653886
X Variable 1	0,037483	0,016812	2,229589	0,0363	0,002618	0,072348

Appendix 10- Regression with pure ECI for low HDI countries

Table XV. HDI as dependent variable pure ECI as independent variable regression for low HDI countries

Regression Statistics	
Multiple R	0,293476
R Square	0,086128
Adjusted R Square	0,020852
Standard Error	0,042664
Observations	16

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0,002402	0,002402	1,319435	0,269941
Residual	14	0,025483	0,00182		
Total	15	0,027885			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0,504418	0,015148	33,29934	9,87E-15	0,471929	0,536907
X Variable 1	0,022393	0,019494	1,148666	0,269941	-0,01942	0,064204