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Towards the Sustainable Nexus of Higher Economic Complexity Index, Lower Carbon Emissions and Accelerated Economic Growth: The case of BRICS Now and Beyond

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Abstract BRICS economies market potential stood at around 3.27 billion individuals in 2023 contributing to 18% of the global exports, yet it remains to be questionable whether their exports have attained the aspired level of technological complexity towards accelerating economic growth. Hence, the main objective of the paper is to estimate how would higher levels of technological advancement envisaged by the Economic Complexity Index (ECI) slash down carbon emissions and bolster economic growth for BRICS economies and other potential members like Egypt. The paper's main theoretical framework is supported by the endogenous, neo classical growth theories and Kuznets curve to articulate the linkages between ECI, carbon emissions and GDP growth. The empirical dataset covers a time frame of 20 years from [2000- 2021] and the analysis' aims to differentiate between short run and long run behavior of ECI and carbon emissions on affecting economic growth. The analysis employs a battery of econometric techniques suitable for panel data to include stationarity tests, panel cointegration, fixed effects, cross section dependence models, cointegration and ARDL (Autoregressive Distributed Lag). The main results stand out to support the theoretical intuition and indicate that higher sophistication and technological content in manufactures maximizes the complexity and value-added content of BRICS country's exports and reduces carbon emissions.

Key words: Economic Complexity Index, Carbon emissions, GDP Growth, Panel cointegration, ARDL, BRICS
JEL codes: F46 , O33, O44

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Introduction

Recently after the COVID-19 followed by aftershocks of inflationary hikes, the global economy has witnessed radical changes in their structure, geopolitics and sudden obstructions and transformation of supply chains. Accordingly, many new regional alliances became the offspring of change and appeared to reduce the reliance on interrupted production, disrupted global supply chains, and low value-added content of trade flows. This shift happened from the hands of few global hubs concentrated in Europe, the U.S and Asia to be more accessible and integrative to emerging and developing economies (Marc,2024). The BRICS alliance went into action to include Brazil, Russia, India, China, and South Africa; to be known as an alliance of emerging countries and it gained traction by its ability to streamline production ,diversify and increase the complexity of trade flows between its members and towards the RoW and particularly the E.U. (Vijayakumar et al, 2010; Wilson & Purushothaman, 2003).

BRICS economies' market size and potential is considerable, as the total population in these countries was around 3.27 billion individuals in 2023, hence contributing to 41.13% of the world population. The alliance's market power renders it attractive to investors due to the high consumer demand and diversity of their resources (Marc,2024). Although, the nominal per capita GDP in all the BRICS countries was estimated at $7,666 in 2021, which is lower when benchmarked to global per capita GDP of $12,263 in the same comparative year, yet their average per capita GDP (PPP) in purchasing power parity terms is $17,990,which is much closer to the global average per capita GDP (PPP) of $18,721. BRICS economies represent 18% of the global exports. More importantly, the E.U. services sector exports for BRICS grew from 8.3% in 2010 to 25% 2022 and China's holds the lion share exports to the E.U and main contributor to the alliance's bolstered growth,

The Choice of BRICS alliance as the main case of this paper is driven by several motives. Firstly, although there is great disparity between the BRICS economies in terms of growth indicators, they thrive at similar developmental pace and are highly dependent on fossil energy due to their industrial nature (Khezri et al., 2022a; Iwaro and Mwasha, 2010). Second, BRICS voting power in the International Bank of Reconstruction and Development (IBRD) is proportional to their countries' financial contribution to the World Bank's funds, which didn't exceed by far 5% during 2023 based on alliance's largest recipient and contributing members Brazil and India. Hence, to mobilize infrastructural and developmental funds needed, some of the BRICS countries established the New Development Bank (NDB) backed up by the Contingent Reserve Agency (CRA) in 2014 to articulate funds, which could be matched to the voting power of BRICS members and at the same time, to reduce complete dependence on dollar trade economies. Third, it is predicted that the BRICS countries will develop their exports complexity envisaged through the Economic Complexity Index (ECI). This index is used to measure exports' sophistication, ubiquity, quality, technological content and ICT weight in the industry and patents adoption of countries. The higher degree of complexity tends to substantially improve their countries' trade structure and composition to culminate higher technological content, be more sophisticated and in parallel accelerate economic growth. The BRICS countries scored different ranges on the ECI scale with South Africa having a relatively lower ICT weight in its manufactures in contrast to China. (Balsalobre-Lorente,2023). Yet, Russia and South Africa emit the highest per capita pollution among BRICS countries, therefore, adding another reason why they should seek higher product sophistication and transform to high technology content economies to achieve sustainable growth.

The Economic Complexity Index (ECI) is used to predict the direct relationship between the degree of product diversification, innovation in production, the expected income level and economic growth for countries. Over the last 10 years, a plethora of endogenous and neoclassical growth theories and extensive literature have emerged and thrown light on the nexus between export sophistication, know-how, innovation diffusion, economic growth and greenhouses gasses emissions (GHG) (Hartmann et al., 2017; Hausmann et al, 2014; Hidalgo & Hausmann, 2009). Hidalgo & Hausmann (2009) defined the economic complexity as an indicator of a nation's actual productive capacity. They defined that capabilities to include intangible inputs such as institutions, technology, and human capital are needed to develop a product. The Capabilities at the functional level include the "know-how" or methods of operation which emerge from people's interactions and close collaboration in a team. The organizational capacity linked to the creation, operation, and management of industrial activities is captured by capabilities at the firm level in a broad sense (Felipe et al. 2012). A country's degree of production is determined by the diversity of its capabilities, which is assessed by economic complexity.

Accordingly, this paper opts to analyze the impact of the ECI on GDP growth rate in BRICS countries plus Egypt. The aim of this paper is primarily to extend beyond BRICS countries and to investigate how through the gradual inclusion of additional members in the alliance, there are unique opportunities for those countries to diversify their products base and achieve higher trade diversification and ubiquity. In parallel, the paper seeks to investigate through the theoretical and empirical evidence, the nexus between economic growth, economic complexity and carbon emissions for the BRICS countries and Egypt. Hence, it identifies the role of carbon emissions and how their intensity could undermine growth in the short run, particularly for BRICS plus the endorsement of new members in the alliance. As for the long run, the paper investigates whether higher levels of economic complexity and technological advancement drive down emissions and lead to the aspired economic growth for their economies . It will also answer interesting questions on whether these countries could face further challenges due to the heterogeneity of their economic activities and reliance on hydrocarbons. It proposes the plan of BRICS economies to minimize emissions meanwhile sustaining growth. The nexus between growth, lower carbon emissions and ECI is theoretically pro-intuitive to the Environmental Kuznets curve (EKC) theory (Duro & Padilla, 2008; Kassouri, &

Altıntaş, 2022; Kuzents,1955;Parker & Bhatti 2020). Then a set of control variables, namely trade openness, Real Effective Exchange Rate (REER) are added to control for overvalued exchange rate and prolonged budget deficits and Foreign Direct Investments (FDI) to reflect on know-how transfer and Human Development Indicators and to capture the determinants of economic growth for BRICS alliance plus Egypt. Some of the relationship between growth and the control variables are still debatable in the literature due to the nature of the BRICS economies, as in the case of Fang et al. (2021). Finally, the literature is polarized between suggesting the mixed, positive or negative impact of FDI on economic growth for Asia and Latin American countries and other regions (Cakerri et al, 2020; Saqib et al,2013;Shawl, 2022).

The empirical modelling approach of the paper will focus on a battery of econometric estimations suitable to the analysis of the panel dataset which ranges from [2000-2021] .Those estimations will include stationarity tests, panel cointegration, Fixed effects cross section dependence models, Autoregressive Distributed Lag (ARDL), Pooled Main Groups (PMG) and heterogeneity panels and which all serve to examine how economic complexity accelerates growth and to account for heterogeneity within and between cross sections for both the long and short run analysis.(Balsalobre-Lorente et al., 2023; Cristelli et al, 2015; Leitão, 2021; Molele & Ncanywa, 2022; Pata, 2021; Rout et al., 2022;Stojkoski & Kocarev, 2017)

Finally, the paper proceeds as follows. Section 2 exposes on the literature review divided into two sections (empirical part that shows the aim and main findings from previous papers and theoretical framework earmarking the related theories on this topic). Next, section 3 provides descriptive and stylized data about BRICS economies followed by section 4 dedicated to the econometric methods. In addition, section 5 shows the main discussion of results and findings and finally section 6 wraps up the paper with main recommendations, limitations and conclusions.

The Literature Review

Endogenous Growth and Neo-classical Growth Theories: Refining the relationship between Economic Complexity and Economic Growth

The reverse causality runs in both directions, as confirmed by the mainstream literature, providing the analysis on the endogenous growth theories. This causality frames the relationship between economic growth estimated through per capita GDP and ECI (Hidalgo & Hausmann, 2009; Jones,2019; Lucas,1972; Romer, 1990; Romer 1989). One stream of the literature adopts Romer's (2018) endogenous growth theoretical belief about innovation, knowledge and human capital and its significant role in increasing the economic growth in the nations. In reciprocity, economic growth stimulates a higher stock of investments in physical and human capital, skills development and knowledge diffusion. (Aghion et al.,1998b; Lucas, 1988; Romer,1990; Solow,1956). The conceptual intuition of the theory was initiated by Lucas (1972) & Romer (1990) and it is mainly challenged by the dependence on exogenous factors to present accumulative physical capital formation and investments flows complemented by a set of internal factors concerning innovation and advancement in technology. A Second perspective on the literature supports Romer's (2018) knowledge-based endogenous growth models, but also extends the argument to investigate the progression of the knowledge-based economy, built upon innovation, R&D, improved absolute, and revealed comparative advantage, exports diversification and complexity and their impact on accelerating growth. In this sense, the knowledge based endogenous growth models revisit Ricardo's comparative advantage (1817) in which specialization and increasing returns to scale is determined through innovation and knowledge diffusion. Equally valid is the relative speed of innovation applied to manufacturing, which introduces product sophistication and leads to heterogeneity in growth trajectories across different regions and sectors Accordingly, this speed of innovation will identify the scale of development across countries of varying income levels and at different developmental pace (Can & Gozgor,2017;Hidalgo & Hausmann, 2009; Jones, 2019;Romer, 1990).

In parallel, another strand of the literature came later to endorse the first wave of neoclassical views of endogenous growth theory. The theory pivots on most of the external growth forces. Those external forces are used purely as proxies to account for economic growth and they vary to include per capita population growth rates, trade openness and foreign direct investment (FDI). They also stress on the role of technological advancement and innovation as an indispensable element of growth and development (see Aghion & Howitt, 1992, 1998a, 1998b; Lucas, 1988; Romer, 1986, 1990; Solow, 1956). According to their views, Foreign direct investment (FDI) and trade openness do not have a lasting impact on economic growth, but they do ultimately mobilize income per capita. Notwithstanding, that some views perceive that relationship between economic complexity and growth as inconsequential, as all countries ultimately reach the same stable condition in the long term as in Lucas (1972), yet the second wave of modern views on neoclassical growth, revisit the same idea of the existence of a long-run relationship between technological complexity and economic growth.

The coexistence of this relation according to their views is dependent on the presence of higher accumulation of physical capital investments, human capital knowledge, institutional quality, demographic, geographic factor endowments and finally the presence of social networks and connectivity between regions. (Acemoglu et al., 2014, 2019; Acemoglu & Robinson, 2012; Aghion & Howitt, 1998b; Grossman & Helpman 1994; Lucas, 1988; Rebelo,1991; Romer,1990). Finally, a considerable realm of the literature extended their analysis on the relationship between technological and economic complexity and growth to be based upon all generations of endogenous growth and comparative advantage theories. In their analysis they included new regions in central Europe, Gulf Cooperation Countries, Sub Saharan Africa, main BRICS members and low-income countries (ElMassah & Hassanein,2023; Molele, & Ncanywa,2022)

Revisiting the Nexus between Economic Growth, Economic Complexity and Carbon Emissions

There is a plethora of studies investigating the impact of ECI on environmental proxy measurements such as carbon emissions, carbon footprint and GreenHouse Gasses (GHG) (Hartmann et al., 2017; Hausmann & Hidalgo, 2011). This literature nexus is justified by the theoretical foundation of the Kuznets Curve (1955), which lends its intuition to the inverted U shape curve explaining the relationship between economic growth indicators and environmental degradation. In a nutshell, the higher the pace of development and growth will show a positive correlation to higher depletion of resources and GHG emissions will intensify in the short-run. This short-term relation is juxtaposed to a more sustained growth coupled with less environmental degradation and more controlled emissions in the long run (Duro & Padilla, 2008; Kassouri, & Altıntaş, 2022; Parker & Bhatti 2020). The main interpretation here relies on how countries during their early development stages depend on exports of semi-industrialized products and low processing and sophistication. Some of those exports are like unprocessed agricultural products and raw minerals and metals, but at later stages, technological transformation will add up to the products' complexity, diversify their specialization away from hydrocarbon intensive manufacturing and exports, which eventually improves environmentally quality and diminishes degradation (Boleti et al., 2021; Tsurumi & Managi, 2010; Zafar et al., 2020).

One strand of literature refers to the presence of low economic complexity of products, which leads to the pronounced presence of higher CO2 emissions, as well, extensive energy consumption and GHG emissions are affiliated to lower economic complexity. On the one hand, some of the conceptual theories are supported through a variety of modeling approaches to employ Fully Modified Ordinary Least Squares models(FMOLS), Dynamic Ordinary Least Squares (DOLS) or Auto-regressive Distributed Lag models (ARDL) to differentiate between the short term and long term cointegration of the variables. The modeling approaches extend to use Westerlund's and Kao's cointegration, in addition to second generation panel models (Balsalobre-Lorente et al., 2022; Khan et al., 2019; Pata, 2021b; Rout et al., 2022). On the other hand, the set of studies reassure that the behavior of ECI with respect to carbon emissions is aligned to the (EKC), where at the start lower economic complexity releases more emissions, but at later stages of development, higher complexity would reverse emissions to lower levels (Balsalobre-Lorente et al., 2022; Chang & Fang, 2022; Pata, 2021a; Saqib et al., 2022).

These studies recently amplified the range of regions applying EKC and using it as a theoretical foundation to include BRICS alliance and G7 countries (Peng et al; 2022; Doğan et al., 2022). There are some studies which have identified a counter intuitive relationship between carbon emissions, ECI and growth; where regions structural transformation from a low to high technological complexity could come at the expense of higher environmental degradation as in the case of Pakistan and the case of the seven top economies ranked on ECI (Martins et al., 2021; Zafar et al., 2020)

The Linkages between FDI and Endogenous Control Variables towards Economic Growth

There has been an extensive debate in the literature on the existence of mixed results regarding the correlation between FDI and economic growth across several regions. On one hand, some papers detect a positive correlation between both, lending their views to Knell & Radosevic (2000). They postulate that FDIs provoke knowledge diffusion and transfer, which could upscale the complexity and sophistication of products and ultimately lead to growth. In parallel, a study on Albania detects the positive linkages between investors' legislations, enhancement of investment, business climate all together and their effect on accelerating growth (Cakerri et al, 2020). On the other hand, there are other studies as in the case of Fang et al. (2021) which have proven mixed results between FDI and factors affecting economic growth for Asian and Latin American countries.

In addition, previous studies have shown inconsistencies across all the regions, when it comes to the positive relationship between FDI and economic growth. This is verified by a study conducted by Joo & Shawl (2022) investigating the relationship of FDI, trade openness, financial development, human capital, economic stability and economic growth in the (BRICS) countries. This study detects an insignificant impact of FDI on most of the growth indicators, however, this relationship reverses to a positive one, when technological heterogeneities are captured and controlled for in the modelling. These disparities are believed to improve countries' developmental pace compared to more stagnant ones studied throughout the panel of countries. The same outcome is generated by Saqib et al. (2013), when a negative relationship was detected between FDI and GDP growth for Pakistan, meanwhile, domestic investments have a higher positive effect on Pakistan's economy. This could happen particularly if FDIs depend on low technology content unprocessed or raw exports not involving sophistication and which do not contribute significantly to growth indicators

Narrowing the Existing Gaps by the Empirical Literature: A Modeling Framework between ECI and Economic Growth rate

Following the previous league of studies, the empirical literature opts to unravel two important points. First to detect the appropriate measures and proxies for economic complexity. In this context, predictions in the empirical literature suggest that further measurements for economic complexity are still needed to fill in the literature gap for better estimations. Traditional measurements have been adopted to include human capital indices, expenditure on R&D to extend to years of education and scientific discoveries (Acemoglu et al., 2014; Barro, 2001;Mankiw et al., 1992; Romer, 1990). However, the traditional indicators fell short of capturing the pace and speed of technological advancement, innovation, ubiquity and diversity of products in a region. In addition, they did not account for the quality of trade institutions and their openness, comparative advantage based on innovation diffusion and how digitalization promotes environmental sustainability when carbon emissions are suppressed (Cristelli et al., 2015; Hartmann et al., 2017; Hausmann et al., 2014;Hidalgo & Hausmann, 2009).

In the context of this analysis, most of the studies employed panel data which could be a curse and a blessing at the same time. It is a curse if it fails to capture the heterogeneity across different regions and explain the differences between regions in attaining higher growth indicators, once ECI and other growth determinants induce the differences across regions. At the same time, it is a blessing as there are a battery of econometric approaches such as panel cointegration, FMOLS, Panel Dynamic Ordinary Least Squares (PDOLS), Fixed effects cross section dependence models, ARDL, panel cointegration; Pooled Main Groups (PMG) and heterogeneity panels; which serve to examine the impact of economic complexity on economic growth and to account for heterogeneity within and between cross sections for both the long and short run analysis.(Balsalobre-Lorente et al., 2023;Cristelli et al, 2015; Leitão, 2021; Molele & Ncanywa, 2022; Pata, 2021; Rout et al., 2022; Stojkoski & Kocarev, 2017).

Second point is related to the differentiation between the short run and long run behavior of economic complexity on per capita economic growth across different regions and nations. Some of the studies suggest inconclusive results in detecting whether there is short run or long run significance and co-integration between economic complexity and how it hastens per capita income or GDP growth as in the case Silaghi et al (2014) & Hartman et al. (2013). Both authors agreed on the presence of both short run and long run significant relationship between economic growth and investment in R&D and productive knowledge using panel cointegration and error correction models across 10 South Eastern and Central European countries and their work was revisited by Pedroni (2004).

The study further controls for a series of macroeconomic and human capital endowments such as gross capital formation, number of employees, enrollment in secondary education and a set of institutional variables. Similarly using the same region but on an amplified panel data comprising 16 countries, Stojkoski & Kocarev (2017) examine the long run relation between productive knowledge, as a proxy to measure complexity and economic growth, but no evident relation in the short run materializes, whereas, Gao & Zhou (2018) disclose a positive and significant relation between a firm's economic complexity and the main growth of macroeconomic indicators such as GDP per capita for over a longer time span of 25 years.

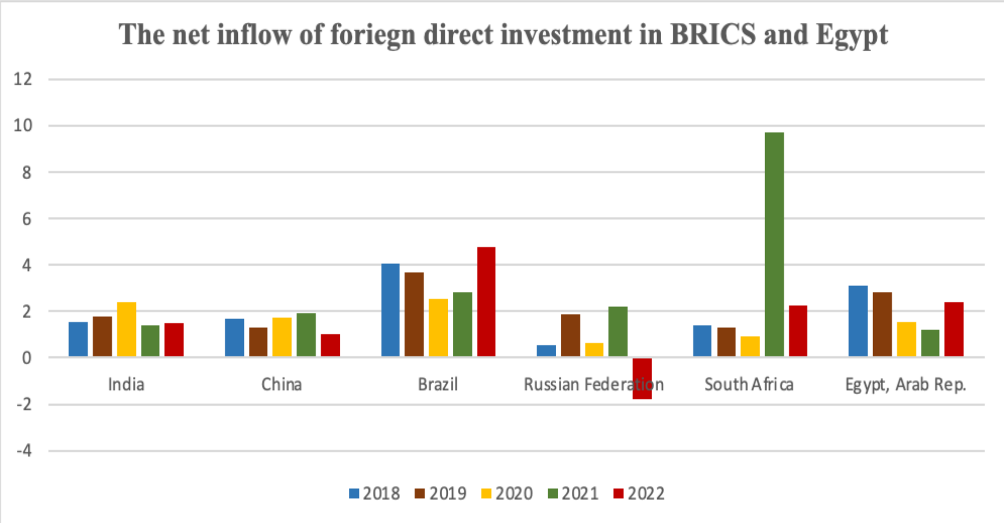
Panel regression with fixed effects across cross-sections as in the case of Hidalgo & Hausmann, (2009) paved the way for many studies to follow and to treat the potential heterogeneity across countries, particularly to interpret the divergences in their growth trajectory between economies is based on technological progress and the diffusion of knowledge, which ultimately affects product sophistication and complexity (Molele & Ncanywa, 2022; Stojkoski & Kocarev , 2017). One of the studies applies the (ARDL) model to balance between the long- and short-term dynamics for how economic growth is affected by ECI and a set of explanatory variables (GDP deflator, household expenditure and REER). The results have proven no short run relationship between ECI and growth, but a long run relation is confirmed to be consistent across all countries introduced in the analysis (Molele & Ncanywa, 2022). Taking a different perspective on growth and employing Gini coefficient, Lee & Vu (2020) disclose that ECI minimizes income inequality across 113 countries via employing a GMM estimator.

Descriptive Data about BRICS Economies

BRICS Economies Stylized Facts

Figure 1 presents a synopsis of the dataset and contrasts between the net inflow of foreign direct investment between BRICS countries and Egypt from 2018 to 2022. Most of BRICS countries and Egypt also have significantly increased the inflows of foreign direct investment except for Russia.

Figure 1: The Net Inflow of Foreign Direct Investment in BRICS countries and Egypt from 2018 to 2022.



Source: (World Bank, 2022)

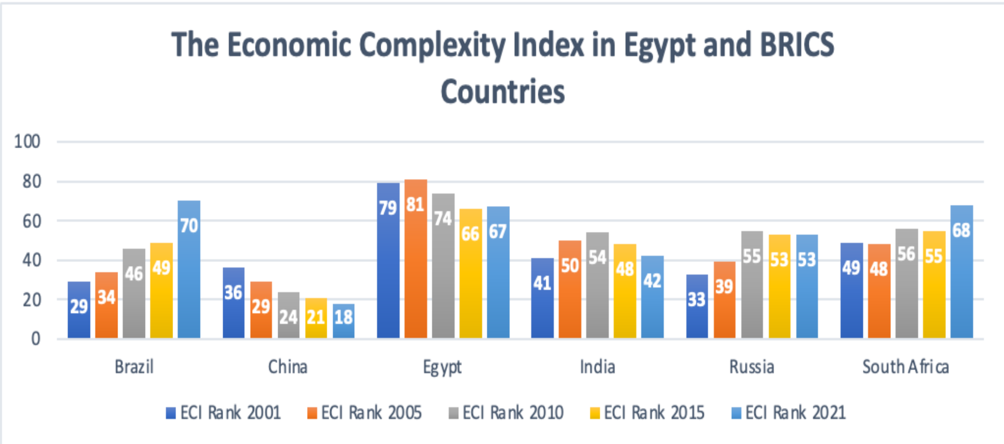
World Economic Forum report (2022) explains the main reason for this significant drop in net inflows of FDIs in Russia in 2022 attributed to several economic sanctions, which were imposed by the United States, Europe and other Western countries. The sanctions were particularly levied on Russia since the onset of the Ukraine-Russian war, and they had their serious repercussions on limiting Russia's access to technologically advanced products (Dubinin, 2022). They also constrained Russia's connection and access to the markets of heavier knowledge , innovation diffusion, and it has cut it off the international financial grid and reduced Russia's outflows of foreign capitals. (McLennan,2022)

Accordingly, many foreign companies decided to relocate their businesses to other foreign and European countries, in addition, Russia prospects for long-term growth were constrained by structural obstacles, including unfavorable demographic patterns, low rates of investments, poor productivity, inadequate institutions, weaker governance, and excessive reliance on the natural resources (Citaristi,2022). All those obstacles drove Russia to lose the competitiveness and attract less foreign capital and it witnessed a significant dive in its FDIs until it plummeted to a lower level during 2022, after several intertwining factors related to geopolitical problems, external shocks, and economic domestic vulnerabilities.

South Africa witnessed a boom in their FDI, particularly in 2021 after the stock market recorded a wave of high spikes. According to UNCTAD's World Investment Report (2022), the substantial foreign transaction in the South African exchange in the third quarter echoed in the country's FDIs. This deal amounted to 45% of the total FDI inflows into Africa, which recorded a historic milestone of $83 billion in 2021. In addition, the country's improved investment climate and infrastructure, the diversification of FDI industries diverted off mining and manufacturing, in addition to the slow but stable recovery from a negative economic performance after the covid 19 pandemic. All those factors contributed to increasing FDI inflows in South Africa over last two years (Mosala, 2022).Although Egypt has been always one of Africa's top FDIs destinations due to its prime location , market potential and access to many fronts, yet it witnessed fluctuations in its FDIs' inflow impacted by external shocks as in the case of 2009 financial crisis, COVID-19 pandemic, however, the inflows picked up once economic stability returned (Hosny et al.,2024).

As for other countries like Brazil rendered one of the promising investment destinations ,as it possesses a market size of over 120 million individuals, yet it still faces many challenges related to work permits , regulations and infrastructural development. Since 2000, China and India have become one of the world's main FDI recipients. For India, FDIs grew by almost 29% to reach USD 64 billion in 2020. Most of the Indian FDI inflows are redirected to sectors of high value added and technological content such as financial services, banking, telecommunications and outsourcing services. China gained traction in becoming one of the biggest investment and capital inflows destinations in Asia and among BRICS countries, given its market size, being a hub of technology, innovation and multinational producers (Yarygina & Krylova , 2023).

Figure 2 : The Economic Complexity Index for Egypt and BRICS Countries to compare 5 years between[2001-2020]



Source: The Growth Lab at Harvard University (2021) (Hausmann et al.2014).

The Ranking of the Economic Complexity Index demonstrates the level of diversity and complexity of a nation 's exports. The lower rank is better, as it indicates that the nation has a higher degree of product sophistication, ubiquity and competitiveness in its exports content based on the FDIs composition knowledge content, several effective patents and research.

Figure 2 shows that Egypt's ranking on the ECI witnessed fluctuations from 79 in 2001 and partially deteriorated to 81 during 2005 and then it has seen a significant improvement to reach 67 in 2021. According to the Observatory of Economic Complexity (2021) Egypt's increase in the ECI rank was based on the country gaining more complexity in the production of refined nitrogenous fertilizers ,petroleum, gas, and gold; however, its performance was not yet up to the aspired level, and it didn't rely on developing products of higher technological content, greater value added and a higher degree of product sophistication. Moving to BRICS, China is associated with one of the highest countries ranked in ECI. China is known to be one of the most diversified and complex economies in its value-added content. China's rank on the ECI has significantly gone up the scale from 36 in 2001 to 18 in 2021, which indicates to a boom in the complexity of their exports.

The Model's Descriptive Data

Table 1 illustrates the variables means, standard deviations, minimum values, maximum values and the units of measurements. It shows that the dependent variable (GDP growth annual) has 132 observations, at the mean value of 4.53% and a standard deviation equal to 3.66%. The Russian Federation records the lowest growth rate of -7.79% in 2009 and the maximum value was China in 2007 to reach 14.23%, which illustrates to the huge discrepancies between the BRICS economies.

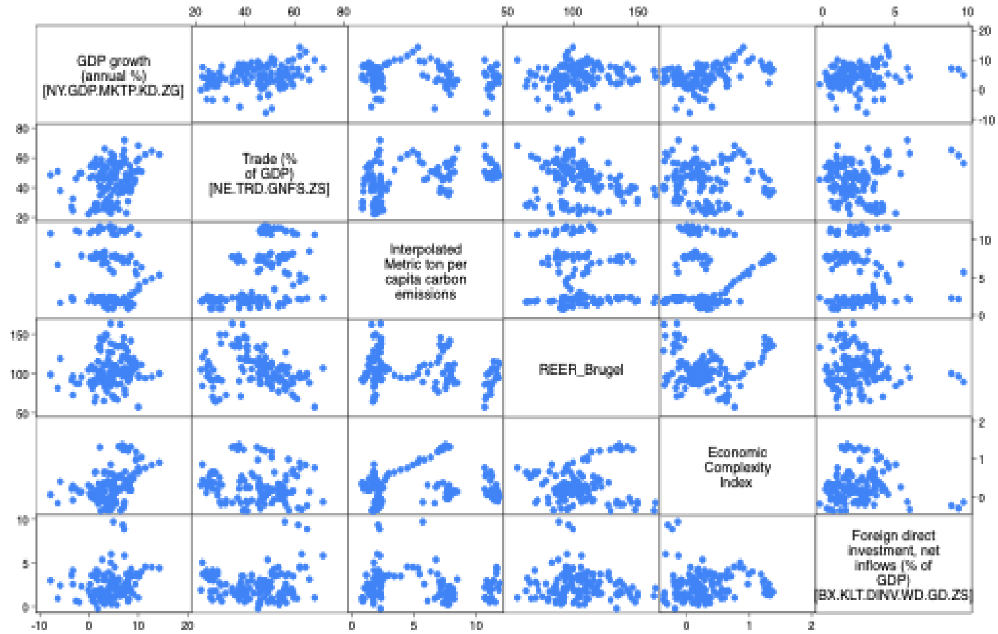
Table 1: The Model's Variables Descriptive Statistics

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Trade openness	Trade percentage of GDP	132	44.6	11.8	22.1	71.7
GDP Growth	Annual Gross Domestic Product Growth rate (%)	132	4.5	3.7	-7.8	14.2
ECI	Economic complex index score	132	0.299	0.429	-0.372	1.378
REER	Real Effective Exchange Rate (2007 base year)	132	104.863	21.131	57.465	163.65
Carbon Emissions	Carbon Emissions in ton per capita	132	5.006	3.679	0.884	11.885
FDI	Foreign Direct Investment net inflows percentage of GDP	132	2.42	1.657	-2.05	9.703
HDI	Human Development Index	132	0.691	0.078	0.491	0.845

Source: Authors' calculation based on data from the World Bank database (2024) for Trade openness, carbon emissions, inflation and FDI; Brugel (2024) for REER, The Growth Lab at Harvard University (2024) for ECI, and UNDP (2024) for HDI.

The first independent variable is the ECI which has 132 observations, its mean value is 0.29 and the standard deviation is 0.429, Egypt had the minimum value of -0.37 in 2002, meanwhile, the maximum value was 1.37 realized by China in 2018. The mean of trade openness reached 44.57, which is aligned to the world's average ratio with Brazil scoring the minimum value of 22.10 in 2009 and Egypt the maximum of 71.68 in 2008. The REER's average value reached 104.8 and it witnessed severe fluctuations among the dataset, as many of its countries were exposed to a series of devaluation. Finally, carbon emissions include 132 observations (noting that the values of 5 additional observations were interpolated) with a mean value of 61.61 tons per capita per annum, and a standard deviation of 38.06 tons per capita per annum, noting that the minimum value of -0.88 was for India in 2001 and the maximum was Russian federation in 2021 at 11.884 tons per capita per annum.

Figure 3: the Matrix of Correlations between the GDP Growth Rate , ECI, Carbon Emissions, Trade Openness and FDI:-



Source: Stata Model's Output

Figure 3 briefly shows the correlation between the variables of interest founded upon the theoretical intuition. Most of the relations have shown to be pro-intuitive relations. First, ECI index shows a U shape for most countries with respect to GDP growth. It is equally plausible as per the endogenous growth theories induced by knowledge transfer and diffusion of innovation. Emerging economies at initial developmental transitions can face a deterioration of ECI in the short run and once they accumulate human and physical capital and technological skills,they start to reach higher complexity on their ECI rankings in the long run and those correlation were supported by the literature as in (Acemoglu et al., 2014, 2019; Acemoglu & Robinson, 2012; Aghion & Howitt, 1998b; Grossman & Helpman 1994; Lucas, 1988; Rebelo,1991; Romer,1990). In parallel, most of the carbon emissions behavior correlation with growth is in consistency with the Kuznets theory and exhibits an inverted U shape, with higher emissions provoked during the early stages of industrialization with a lower complexity and as countries start to rely on cleaner technologies, they start to reduce emissions in the long run (see: Duro & Padilla, 2008;Kassouri, & Altıntaş, 2022; Parker & Bhatti 2020). As for FDI and trade openness, they usually show a positive correlation to GDP growth rate for most of the BRICS and Egypt; yet sometimes results could be mixed as proposed by the theoretical and empirical literature (Fang et al.,2021; Sabiq et al., 2013;Shawl, 2022).

Empirical Section: Modeling Approach

The paper employs a panel dataset formed of the five founder BRICS countries and Egypt over a timeframe to start from 2000 to 2021 and it analyzes the relationship between the GDP annual growth rate and each of the Economic Complexity Index and carbon emissions. In addition to the main variables of interest, the paper includes a set of other determinants of economic growth, namely, trade openness (TO), Real Effective Exchange Rate (REER) to control the overvalued exchange rate and prolonged budget deficits, and Foreign Direct Investments (FDI) as a percentage of GDP. The econometric estimation starts with ordinary pooled least squares, and fixed effects model. Then, a co-integration test is performed, and a panel Autoregressive Distributed Lag Model (ARDL) is estimated to investigate the short-run and long-run relationships between the variables. ARDL has two main advantages. First, it can accommodate a mixture of stationary and nonstationary variables without the need for pretesting the order of integration (although the study performs the co-integration test for robustness check). Moreover, the short-run and long-run coefficients can be consistently estimated with asymptotic normality (Kripfganz & Schneider, 2023).

The general form of the model adopted in the study is as follows

$$GDPG = \alpha + \beta Xit + \gamma Cit + vi + \varepsilon it, \ldots\ldots \textbf{Eq.(1)}$$

where: GDPG is GDP annual growth rate,

In Equation 1, X represents the main independent variables of interest which are Economic Complexity Index (ECI), and Carbon Emissions (CO), and C represents the other independent variables which affect economic growth rate envisaged in Trade Openness (TO), Real Effective Exchange Rate (REER), Foreign Direct Investment (FDI) as a percentage of GDP and Human Development Index (HDI).

Discussion of Main Results and Findings

This section will include the main results and findings of the econometric estimations . It sets off with the residual and coefficient diagnostic tests to validate the choice of the final modeling approach.

The Modelling Plan Proposed

The first diagnostic tests start with the cross-sectional dependence to verify the absence of autocorrelation across cross sections, panel unit root tests benchmarking the "Levin-Lin-Chu" (LLC) to other ones such as the "Breitung test" for stationarity. Those two stationarity tests were particularly adopted as they adjust for cross section dependence. Then, it proceeds to Variance of Inflated factors (VIF) to identify serious cases of multicollinearity and finally heteroskedasticity test to detect presence or absence of non-constant variance and severe heterogeneity across countries. The econometric estimation finally provides a contrast between comparable regression results through employing the "Pooled OLS", "Fixed-Random Effects and Hausman Test", "Feasible Generalized Least Square Model" (FGLSM) to control for presence of cross-sectional dependence. As well, the use of "Kao- Cointegration test" was justified; given that across most of the panel, it is evident that there is stationarity at first difference. Finally, "Panel Auto regressive Distributed Lag Model" (ARDL) will be conducted to provide clear contrast between the short and long-run dynamic relationship between ECI , carbon emissions and growth rate.

Cross-Sectional Dependence

The cross-sectional dependence test is performed using the "Pesaran Cross-Dependence" (CD) test. The null-hypothesis of the test is the non-existence of cross-sectional dependence (Pesaran 2004). At a p-value of 0.000, the null hypothesis is rejected at the 1% level, which indicates that the data shows evidence of cross-sectional dependence. The presence of cross-sectional dependence implies the model could be re-estimated using the Feasible Generalized Least Squares Model (FGLS) to account for cross-sectional dependence, as well as heteroskedasticity in case it exists in alignment to (see Leitão, 2021; Pata, 2021; Rout et al., 2022). In addition, the tests selected for panel unit root tests should capture the existence of cross-section dependence particularly "Breitung test" and LLC assumes common unit roots across cross sections which increases robustness of testing particularly for bigger datasets.

Panel Unit-Root Tests

The panel unit root tests show that all the model variables become stationary at the first lag and first difference, as per the null hypothesis of rejecting non-stationarity at highly significant p-values of 000 (Appendix 1; Table A1). The study employed the Levin-Lin-Chu unit-root test and Breitung as they are adjusted for cross-section dependence to achieve robustness.

Variance Inflation Factor

The Variance Inflation factor is a post-diagnostic metric estimated to examine multicollinearity of the variables included in a regression model through quantifying the degree to which the standard errors (and hence the variances) are inflated in the model. Table (3) shows the Variance Inflation Factor (VIF) for the independent variables included in the study. A general rule of thumb is that a VIF value of greater than 5 warrants further investigation, while a VIF exceeding 10 indicates to the presence of serious multicollinearity (Kim 2019). Given that the VIF of all variables is below 5, we can conclude that there is no serious risk of multicollinearity among the variables included in the model.

Table 3 : Variance Inflation Factor Results (VIF)

	VIF	1/VIF
CO2 emissions	4.101	.244
Trade openness	3.044	.328
HDI	2.872	.348
REER	2.274	.44
FDI	1.344	.744
ECI	1.263	.792
GDP Growth	1.156	.865
Mean VIF	2.293	.

Source: Authors’ own calculation

Heteroskedasticity Test

The Breusch-Pagan/Cook Weisberg test for heteroskedasticity was employed and it yields a p-value of 0.1239, the null hypothesis of constant variance is not rejected at any of the conventional significance levels, and it means data is homoscedastic, which verifies a constant variance and less variability across all variables (shown in table 4)

Table 4 : Breusch-Pagan/Cook Weisberg Test for Heteroskedasticity

Breusch,ÄìPagan/Cook,ÄìWeisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of GDP_Growth
H0: Constant variance Chi2(1) =2.37 Prob>Chi2=0.1239

Source: Authors' own calculation

Regression Analysis Results

Pooled Ordinary Least Squares (POLS) Model

Table 5 shows the results of the estimation using the POLS. As indicated above, the model tests did not indicate heteroscedasticity according to Breusch-Pagan/Cook Weisberg test. Also, no problem of multicollinearity is detected given that the VIF values for all variables are below 5. The results are pro-intuitive to the theoretical and empirical literature showing a negative relationship between that economic growth and CO2 emission (carbon emissions) at lower levels of significance (Acemoglu et al., 2019; Acemoglu & Robinson, 2012; Altıntaş, 2022; Parker & Bhatti 2020). The lower levels of significance of the results are consistent to results interpreting the possibility of existing heterogeneity across BRICS countries, particularly divergences in their growth trajectory, technological progress and the diffusion of knowledge, which ultimately affects product sophistication and complexity and leads to insignificant results for carbon emissions (Molele & Ncanywa, 2022; Stojkoski & Kocarev, 2017). The presence of significant positive relationship ECI, and FDI with repsect to economic, re-asserts that BRICS countries and Egypt, are on the correct trajectory to upgrade their export' sophistication, diversity and they have exclusive exports of high value technological content , which only few countries globally can export. Throughout the POLS estimation, the rest of control variables have shown their expected signs with exception to HDI, which varies across BRICS countries due to the disparities in educational attainment and fluctuation in educational and human development performance indicators between across member countries (Kaur et al., 2022).

Table 5 : Pooled Ordinary Least Squares Results

GDP Growth	Coef.	St.Err.	t-value	p-va	[95% Conf	Interval]	Sig
ECI	4.379	.602	7.27	0	3.186	5.572	***
Carbon Emissions	-.238	.129	-1.85	.067	-.493	.017	*
Trade openness	.051	.034	1.48	.141	-.017	.118	
HDI	-.10.4	5	-2.07	.041	--20.4	-0.4	**
FDI	.54	.173	3.13	.002	.198	.882	***
REER	-.102	.026	-3.86	0	-.154	-.05	***
Constant	8.82	3.718	2.37	.019	1.459	16.182	**
Mean dependent var		4.461	SD dependent var		3.714		
R-squared		0.534	Number of obs		126		
F-test		22.732	Prob > F		0.000		

****** p<.01, ** p<.05, * p<.1***

Source: Authors' own calculation

Fixed and Random Effect Models and Hausman Test

The Breusch and Pagan Multiplier tests and its hypothesis exhibited in table 6, indicate whether variances across entities are equal to zero. This hypothesis is rejected for the model. This indicates that there is a panel effect and that the random effect model is better than the pooled ordinary least squares model. The Hausman specification test examines whether the individual characteristics are not correlated with the regressors (The null hypothesis is that there is a random effect). That null hypothesis is rejected which means that the fixed effects model should be used.

Table 6: Fixed Effects and Random Effects Model Results

Fixed-Effects Model				**Random Effects Model**		
GDP Growth	**Coef.**	**Sig**	**St.Err.**	**Coef.**	**Sig**	**St.Err.**
ECI	3.219	**	1.364	4.379	***	.602
Carbon Emissions	.187	*	.475	-.238	*	.129
Trade openness	.08	**	.033	.051		.034
HDI	-.31.1	***	7.9	-10.4	**	5.1
FDI	.199		.182	.54	***	.173
REER	-.132	***	.045	-.102	***	.026
Constant	20.95 4	***	4.624	8.82	**	3.718

R-squared	0.370	R-squared	
F-test , Prob > chi2	0.000	F-test , Prob > chi2	0.000
Hausman Test	0.000	Beurch and Pagan Multiplier test	0.000

**** p<.01, ** p<.05, * p<.1*

Source: Authors' own calculation

Feasible Generalized Least Squares Model (FGLS)

The Feasible Generalized Least Squares is estimated to account for cross-sectional dependence. The model results are consistent to the results of the random effects model. Table 7 sheds light on the positive significant relationship between economic growth and ECI. An increase in economic complexity score by 1 point, increases GDP growth rate by 4.4 percentage points. Given the small range of the data of the variable ECI as the score ranges from -0.4 to 1.4 in the dataset, and from -2.5 to 2.5 globally, it could be deduced that an increase in ECI by one tenth leads to an increase in GDP annual growth rate by 0.4 percentage points. The FGLS shows varying degrees of significance across most of the variables with ECI, FDI, REER at highest levels of significance, CO2 emissions and trade openness at acceptable levels of significance. Most of the variables' behavior and their signs are pro-intuitive, when benchmarked to other studies with the exception to HDI for the same reason of conflicting educational attainment and development indicators mentioned earlier across BRICS originally (Molele & Ncanywa, 2022; Kaur et al., 2022; Stojkoski & Kocarev, 2017).

Table 7: Results of the Generalized Feasible Least Squares Model (FGLS)

GDP Growth	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Trade Openness	.104	.027	3.80	0	.05	.158	***
CO2 emissions	-.076	.118	-0.65	.515	-.307	.154	*
REER_Brugel	.048	.011	4.43	0	.027	.07	***
HDI	-18.209	4.697	-3.88	0	-27.416	-9.003	***
ECI	4.498	.549	8.19	0	3.421	5.574	***
FDI	.415	.145	2.87	.004	.131	.699	***
Constant	4.123	3.495	1.18	.238	-2.727	10.973	

Mean dependent var	**4.533**	**SD dependent var**	**3.669**
Number of obs	**132**	**Chi-square**	**165.633**
Prob > chi2	**0.009**	**Akaike crit. (AIC)**	**625.432**

****** p<.01, ** p<.05, * p<.1***

Source: Authors' calculation

Kao Cointegration Test :

The KAO test as described in Kao (1999) assumes the same cointegrating vector is unified across all panels. Kao tests estimate panel-specific means and do not allow a time trend based on the following the cointegrating relationship:

yit = γi + x 0 itβ + eit where γi denotes panel-specific means (fixed effects).

The null hypothesis of the Kao test is that there is no cointegration among the series. The alternative hypothesis is that the series in all panels are cointegrated with the same cointegrating vector. In Table 8, all test statistics reject the null hypothesis of no cointegration in favor of the alternative hypothesis of the existence of a cointegrating relation among the model variables. The modified DF t, and the ADF t test statistics are adjusted for serial correlation. This means that there is a long-run relationship between the model variables after an average of 1.5 years, even if some deviation temporarily happens in the short run. Finally, the ARDL model re-estimates the long-run and short-run relationships between the variables.

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Table 8: Results of the KAO Cointegration Test

H0: No cointegration	**Number of panels = 6**	
Ha: All panels are cointegrated	**Number of periods = 19**	
Cointegrating vector: Same		
Panel means: Included Kernel:	**Bartlett**	
Time trend: Not included Lags:	**1.50 (Newey,ÄìWest)**	
AR parameter: Same	**Augmented lags: 1 (AIC)**	
Modified Dickey,ÄìFuller	-3.21	0.0007
Dickey,ÄìFuller	-2.46	0.0070
Augmented	-2.61	0.0046
Unadjusted modified Dickey,ÄìFuller	-7.18	0.0000
Unadjusted Dickey,ÄìFuller	-3.69	0.0001

Source: Authors' calculation

The Panel Auto-Regressive Distributed Model (ARDL)

As shown in the results of Table (9) in the appendix, the economic Complexity index is significant at 1 with a positive relationship with the GDP annual growth. The coefficient indicates that with each increase in the economic complexity index by 1-unit, the dependent variable as the GDP annual growth should increase by 4.22 percentage points holding everything else constant. This verifies how economic complexity can stimulate growth on the long run for most of the BRICS alliance countries and could integrate other new members to improve on their product industrialization and sophistication. The trade openness is significant at 1 % with a positive relationship with the GDP annual growth. The coefficient indicates that with each increase in the trade openness by 1-unit, the dependent variable as the GDP annual growth should increase by 0.248 percentage points holding everything else constant.

Furthermore, CO_2 emissions are significant at 5 % with a negative relationship with the GDP annual growth. The coefficient indicates that with each increase in the CO_2 emissions by ton per capita, the dependent variable as the GDP annual growth should decrease by 0.8 percentage points holding everything else constant but at lowest significance possible. The carbon emission in relation to GDP growth has captured the expected sign for the long run behavior as echoed by Boleti et al. (2021),Tsurumi & Managi (2010) & Zafar et al (2020).For the short run error correction, the short run relationship between carbon emission and growth is counter intuitive in this context and it can be interpreted that the adoption of ECI, using quicker and cleaner technology will eventually add up to the products' complexity, intensify specialization in exports of lower carbon footprint and reduce the size of emissions and improve environmental quality and curtail degradation (Boleti et al., 2021; Tsurumi & Managi, 2010; Zafar et al., 2020).

The real effective exchange rate is significant at 5 % in relation to the GDP annual growth. The coefficient indicates that with each decrease in the real effective exchange rate by 1-unit, the dependent variable as the GDP annual growth should decrease by 0.09 percentage points holding everything else constant. Finally, in compatibility with previous results negative or positive result between FDI and GDP growth will depend on the region as in the case of Fang et al. (2021); which demonstrates mixed results between FDI and its factors affecting economic growth for Asian and Latin American countries and Saqib et al.(2013) for Pakistan. In addition, previous studies have shown inconsistencies across all the regions. Hence, the coefficient indicates that with each increase in net FDI as a share of GDP by one percentage point, the dependent variable as the GDP annual growth will be reduced by 0.80 percentage points holding everything else constant. Finally, the negative HDI coefficient interprets the presence of high-income inequality in some of the BRICS countries such as China and India, which might prevent the effects of higher human development indicators to proliferate and accelerate economic growth (Adrián Risso &Sánchez Carrera,2012).

Conclusion, limitations and Future lines of Research

This paper investigates the close linkages between ECI, carbon emissions and economic growth for the BRICS countries and beyond for more members to join the alliance. The paper's main theoretical arguments are supported by the endogenous growth theory , neo classical growth theories and Kuznets curve and many more to articulate the intricate linkages between the three variables. The empirical analysis'main aim was to differentiate between short run and long run behavior precisely for the close nexus holding an impact of ECI and carbon emissions on economic growth. It has indeed shown that higher product sophistication and technological content in manufactures maximizes the complexity and value-added content of BRICS country's exports. At the same time, it has shown effective results on reducing carbon emissions and reducing environmental degradation. There are no doubts that those results would induce policy implications that would be suitable to differentiate between the short run and long run time frames and use the appropriate policy designed for each of the alliance's countries to achieve better and more sustainable growth indicators.

In the short run countries like the BRICS should realize that ECI would not necessarily lead to ultimate economic growth, as they need time to realize the scalability of their exports complexity and sophistication , whereas, the long run results, for most of the analysis, suggest that ECI is highly significant and effective on sustainable growth. It particularly happens that in the long-run carbon emissions start to gradually diminish and stabilize, though it could increase or decrease depending on the individual characteristics of the BRICS country. Then, it becomes obvious that BRICS countries New Development Bank (NDB) must play a future role in supporting their access towards sustainable funds to promote R&D and patents to improve their countries' exports' technological content and realize the shift towards a cleaner technology-based products and promote trade of environmentally friendly goods and low carbon footprint.

The results would even be more pronounced given a set of socioeconomic and developmental indicators are adopted to reduce income inequality and to harmonize the HDI fluctuations between BRICS countries particularly in the case of China and India. Both countries are known to the have the highest per capita growth driven economies, yet they face income imbalances, when contrast them other South Africa and Brazil which face other challenges related to environmental degradation. An in-depth analysis on sector-by-sector approach and classification of ICT exports for BRICS countries or introducing exports of higher technological content; given data could be supported, will prompt precise insights and articulate policy directives and recommendations to be designed for specific sectors in the alliance. Finally, Future lines of research should then extend to capture and separate between the individual heterogenous effects for each country in BRICS and provide more insights on the specific policies targeting each country to synchronize between their countries' economic policies and support the endorsement of many more members into the alliance without undermining its comparative advantage and its purpose.

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Appendix of Tables

Table A1: Stationarity Benchmark Tests

Levin- Lin- Chu unit-root test for Stationarity							
	GDP Growth	**ECI**	**FDI**	**REER_ Brugel**	**Carbon Emissions**	**HDI**	**Trade openness**
P-value	0.1180	0.0707	0.0679	0.2170	0.1148	0000	0.1138
Breitung unit-root test for stationarity							
P-value	**GDP Growth**	**ECI**	**FDI**	**REER_ Brugel**	**Carbon Emissions**	**HDI**	**Trade openness**
	0.000	0.967	0.0672	0.3985	0.9034	0000	0.3385

Source: Author’s own calculation

Table A2: Autoregressive distributed Lag (ARDL)

Number of obs = 126
Time Variable (t): time
Number of groups = 6
Obs per group: min = 21
avg = 21.0
max = 21
Log Likelihood = -221.9981

GDP-Growth	Coefficient	Std. err.	z	P>z	[5% conf. interval]	
__ec						
Trade_Openness	0.248	0.043	5.790	0.000	0.164	0.331
Carbon_Emissions	-0.810	0.545	-1.490	0.137	-1.878	0.259
REER_Brugel	0.090	0.021	4.390	0.000	0.050	0.130
HDI	-31.219	7.358	-4.240	0.000	-45.641	-16.796
ECI	4.225	1.654	2.550	0.011	0.983	7.467
FDI	-0.805	0.214	-3.770	0.000	-1.224	-0.386
SR						
__ec	0.808	0.215	3.760	0.000	0.387	1.228
Trade Openness						
D1.	0.271	0.121	2.230	0.025	0.033	0.509
Carbon_emissions						
D1.	-3.355	2.258	-1.490	0.137	-7.781	1.070
REER_Brugel						
D1.	0.038	0.054	0.710	0.480	-0.067	0.143
HDI						
D1.	-69.110	37.502	-1.840	0.065	-142.613	4.393
ECI						
D1.	0.271	2.490	0.110	0.913	-4.609	5.152
FDI						
D1.	-0.250	0.593	-0.420	0.673	-1.413	0.912
_cons	-7.204	2.424	-2.970	0.003	-11.955	-2.453

Source: Authors' own calculation

.References:

Acemoglu, D., Gallego, F. A., & Robinson, J. A. (2014). Institutions, human capital, and development. Annu. Rev. Econ., 6(1), 875-912. https://doi.org/10.1146/annurev-economics-080213-041119

Acemoglu, D., Naidu, S., Restrepo, P., & Robinson, J. A. (2019). Democracy does cause growth. Journal of political economy, 127(1), 47-100. https://doi.org/10.1086/700936

Adrián Risso, W., & Sánchez Carrera, E. J. (2012). Inequality and economic growth in China. Journal of Chinese Economic and Foreign Trade Studies, 5(2), 80-90. https://doi.org/10.1108/17544401211233453

Aghion, P., Howitt, P., Brant-Collett, M., & García-Peñalosa, C. (1998). Endogenous growth theory. MIT press.

Bahar, D., Hausmann, R., & Hidalgo, C. A. (2014). Neighbors and the evolution of the comparative advantage of nations: Evidence of international knowledge diffusion?. Journal of International Economics, 92(1), 111-123. https://nrs.harvard.edu/URN-3:HUL.INSTREPOS:37366260

Balsalobre-Lorente, D., dos Santos Parente, C. C., Leitão, N. C., & Cantos-Cantos, J. M. (2023). The influence of economic complexity processes and renewable energy on CO2 emissions of BRICS. What about industry 4.0?. Resources Policy, 82, 103547. https://doi.org/10.1016/j.resourpol.2023.103547

Barro, R. J. (2001). Human capital and growth. American economic review, 91(2), 12-17.

Boleti, E., Garas, A., Kyriakou, A., & Lapatinas, A. (2021). Economic complexity and environmental performance: evidence from a world sample. Environmental modeling & assessment, 26(3), 251-270. https://www.jstor.org/stable/2677725

Boleti, E., Garas, A., Kyriakou, A., & Lapatinas, A. (2021). Economic complexity and environmental performance: evidence from a world sample. Environmental modeling & assessment, 26(3), 251-2.https://doi.org/10.1007/s10666-021-09750-0

Breitenbach, M. C., Chisadza, C., & Clance, M. (2022). The Economic Complexity Index (ECI) and output volatility: High vs. low-income countries. The Journal of International Trade & Economic Development, 31(4), 566-580. https://doi.org/10.1080/09638199.2021.1995467

Brugel (2024). Real effective exchange rates for 178 countries: a new database. https://www.bruegel.org/publications/datasets/real-effective-exchange-rates-for-178-countries-a-new-database

Can, M., & Gozgor, G. (2017). The impact of economic complexity on carbon emissions: evidence from France. Environmental Science and Pollution Research, 24, 16364-16370. DOI 10.1007/s11356-017-9219-7

Cakerri, L., Muharremi, O., & Madani, F. (2020). An empirical study in Albania of foreign direct investments and economic growth relationship. International Journal of Economics and Financial Issues, 10(2), 193. https://doi.org/10.32479/ijefi.9294

Chang, C. L., & Fang, M. (2022). Renewable energy-led growth hypothesis: New insights from BRICS and N-11 economies. Renewable Energy, 188, 788-800. https://doi.org/10.1016/j.renene.2022.02.052

Citaristi, I. (2022). Organisation For Economic Co-Operation And Development—OECD. In The Europa Directory of International Organizations 2022 (pp. 694-701). Routledge.

Cristelli, M., Tacchella, A., & Pietronero, L. (2015). The heterogeneous dynamics of economic complexity. PloS one, 10(2), e0117174. https://doi.org/10.1371/journal.pone.0117174

Doğan, B., Ghosh, S., Hoang, D. P., & Chu, L. K. (2022). Are economic complexity and eco-innovation mutually exclusive to control energy demand and environmental quality in E7 and G7 countries?. Technology in Society, 68, 101867. https://doi.org/10.1016/j.techsoc.2022.101867

Dubinin, S. K. (2022). Russia’s financial system under sanctions: Logic of confrontation. Russia in Global Affairs, 20(4), 82-102. DOI: 10.31278/1810-6374-2022-20-4-82-102

Duro, J. A., & Padilla, E. (2008). Analysis of the international distribution of per capita CO2 emissions using the polarization concept. Energy Policy, 36(1), 456-466. https://doi.org/10.1016/j.enpol.2007.10.002

ElMassah, S., & Hassanein, E. A. (2023). Economic development and environmental sustainability in the GCC countries: new insights based on the economic complexity. Sustainability, 15(10), 7987. https://doi.org/10.3390/su15107987

Fang, J., Collins, A., & Yao, S. (2021). On the global COVID-19 pandemic and China's FDI. Journal of Asian Economics, 74, 101300.doi 10.1016/j.asieco.2021.101300

Gao, J., & Zhou, T. (2018). Quantifying China's regional economic complexity. Physica A: Statistical Mechanics and its Applications, 492, 1591-1603. https://arxiv.org/pdf/1703.01292

Grossman, G. M., & Helpman, E. (1994). Foreign investment with endogenous protection.

Hartman, M., Martin, A. B., Benson, J., Catlin, A., & National Health Expenditure Accounts Team. (2013). National health spending in 2011: overall growth remains low, but some payers and services show signs of acceleration. Health affairs, 32(1), 87-99. https://doi.org/10.1377/hlthaff.2012.1206

Hartmann, D., Guevara, M. R., Jara-Figueroa, C., Aristarán, M., & Hidalgo, C. A. (2017). Linking economic complexity, institutions, and income inequality. World development, 93, 75-93. https://arxiv.org/pdf/1505.07907

Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. Proceedings of the national academy of sciences, 106(26), 10570-10575 https://doi.org/10.1073/pnas.0900943106

Hausmann, R., & Hidalgo, C. A. (2011). The network structure of economic output. Journal of economic growth, 16, 309-342. DOI 10.1007/s10887-011-9071-4

Hosny Elazhary, R., Tohamy Eltayb, A., & Hamdy Hashem, A. (2024). Foreign Direct Investment and industry value-added in Egypt: Economic complexity threshold analysis. المجلة المصرية للدراسات التجارية, 48(2) , 779-807. Doi 10.21608/alat.2024.363628

Joo, B. A., Shawl, S., & Makina, D. (2022). The interaction between FDI, host country characteristics and economic growth? A new panel evidence from BRICS. Journal of Economics and Development, 24(3), 247-261. DOI 10.1108/JED-03-2021-0035

Jones, C. I. (2019). Paul Romer: Ideas, nonrivalry, and endogenous growth. The Scandinavian Journal of Economics, 121(3), 859-883.
https://doi.org/10.1111/sjoe.12370

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. Journal of econometrics, 90(1), 1-44. https://doi.org/10.1016/S0304-4076(98)00023-2

Kassouri, Y., & Altıntaş, H. (2022). The quantile dependence of the stock returns of "clean" and "dirty" firms on oil demand and supply shocks. Journal of Commodity Markets, 28, 100238. https://doi.org/10.1016/j.jcomm.2021.100238

Kaur, H., Kaur, M., & Soni, M. (2022, June). Hdi growth: A comparative analysis of Brics economies using data analytics. In Proceedings of the International Conference on Innovative Computing & Communication (ICICC). http://dx.doi.org/10.2139/ssrn.4126160

Khan, M. K., Teng, J. Z., & Khan, M. I. (2019). Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach. Environmental Science and Pollution Research, 26, 23480-23490. https://doi.org/10.1007/s11356-019-05640-x

Kim, JH. (2019). Multicollinearity and misleading statistical results. Korean J Anesthesiol. ;72(6):558-569. doi: 10.4097/kja.19087. DOI: https://doi.org/10.4097/kja.19087

Knell, M., & Radosevic, S. (2000). FDI, technology transfer and growth in economic theory. Integration Through Foreign Direct Investment: Making Central European Industries Competitive, 28-49.

Kripfganz, S., & Schneider, D. C. (2023). ARDLl: Estimating autoregressive distributed lag and equilibrium correction models. The Stata Journal, 23(4), 983-1019. DOI: 10.1177/1536867X231212434

Kuznets, S. (1955). Population, income and capital. In Economic Progress: Proceedings of a Conference held by The International Economic Association

at Santa Margherita Ligure, Italy (pp. 3-20). London: Palgrave Macmillan UK.
https://doi.org/10.1111/1468-2451.00141

Lee, K. K., & Vu, T. V. (2020). Economic complexity, human capital and income inequality: a cross-country analysis. The Japanese Economic Review, 71(4), 695-718. https://doi.org/10.1007/s42973-019-00026-7

Leitão, N. C. (2021). Testing the role of trade on carbon dioxide emissions in Portugal. Economies 9 (1): 22. https://doi.org/10.3390/economies9010022

Li, Z., Chu, Y., & Fang, H. (2022). Hierarchical Education Investment and Economic Growth in China. SAGE Open, 12(2), 21582440221108159. https://doi.org/10.1177/2158244022110815

Lucas Jr, R. E. (1972). Expectations and the Neutrality of Money. Journal of economic theory, 4(2), 103-124. https://doi.org/10.1016/0304-3932(88)90168-7

Lucas Jr, R. E. (1988). On the mechanics of economic development. Journal of monetary economics, 22(1), 3-42. https://doi.org/10.1016/0304-3932(88)90168-7

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. The quarterly journal of economics, 107(2), 407-437. https://doi.org/10.2307/2118477

Mosala, S. (2022). The South African Economic Reconstruction and Recovery Plan as a response to South African economic crisis. Journal of BRICS Studies, 1(1), 55-67. https://orcid.org/0000-0002-6305-436X

Marc, J. U. T. T. E. N. (2024). Expansion of BRICS: A quest for greater global influence? 20.500.12592/qjq2j25

Martins, J. M., Adebayo, T. S., Mata, M. N., Oladipupo, S. D., Adeshola, I., Ahmed, Z., & Correia, A. B. (2021). Modeling the relationship between economic complexity and environmental degradation: evidence from top seven economic complexity countries. Frontiers in Environmental Science, 9, 744781. https://doi.org/10.3389/fenvs.2021.744781

McLennan, M. (2022). The global risks report 2022 17th edition. Cologny, Switzerland: World Economic Forum. https://tatsigroup.com/fa/wp-content/uploads/2022/02/the-global-risks-report-2022.pdf

Molele, S. B., & Ncanywa, T (2022). Effects of Economic Complexity as A Development Index on Economic Performance: A Sub-Saharan Africa and BRICS Comparative Analysis.The Journal of Social Sciences and Humanities. http://www.jssshonline.com/

Pata, U. K. (2021). Linking renewable energy, globalization, agriculture, CO2 emissions and ecological footprint in BRIC countries: A sustainability perspective. Renewable Energy, 173, 197-208. https://doi.org/10.1016/j.renene.2021.03.125

Parker, S., & Bhatti, M. I. (2020). Dynamics and drivers of per capita CO2 emissions in Asia. Energy Economics, 89, 104798. https://doi.org/10.1016/j.eneco.2020.104798

Pesaran, M. H. (2004). General Diagnostic Tests for Cross Section Dependence in Panels. CambridgeWorking Paper in Economics 0435 https://cir.nii.ac.jp/crid/1370002214340987648

Peng, G., Meng, F., Ahmed, Z., Ahmad, M., & Kurbonov, K. (2022). Economic growth, technology, and CO2 emissions in BRICS: Investigating the non-linear impacts of economic complexity. Environmental Science and Pollution Research, 29(45), 68051-68062. https://doi.org/10.1007/s11356-022-20647-7

Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric theory, 20(3), 597-625. https://doi.org/10.1017/S0266466604203073

Rebelo, S. (1991). Long-run policy analysis and long-run growth. Journal of political Economy, 99(3), 500-521. https://doi.org/10.1086/261764

Romer, P. M. (1989). What determines the rate of growth and technological change? (Vol. 279). World Bank Publications.

Romer, P. M. (1990). Endogenous technological change. Journal of political Economy, 98(5, Part 2), S71-S102. https://doi.org/10.1086/261725

Rout, S. K., Gupta, M., & Sahoo, M. (2022). The role of technological innovation and diffusion, energy consumption and financial development in affecting ecological footprint in BRICS: an empirical analysis. Environmental Science and Pollution Research, 1-18. https://doi.org/10.1007/s11356-021-17734-6

Saqib, N., Masnoon, M., & Rafique, N. (2013). Impact of foreign direct investment on economic growth of Pakistan. Advances in Management & Applied Economics, 3(1), 35-45. https://ssrn.com/abstract=2207626

Saqib, N., Usman, M., Radulescu, M., Sinisi, C. I., Secara, C. G., & Tolea, C. (2022). Revisiting EKC hypothesis in context of renewable energy, human development and moderating role of technological innovations in E-7 countries?. Frontiers in Environmental Science, 10, 1077658. https://doi.org/10.3389/fenvs.2022.1077658

Saqib, N., Ozturk, I., & Usman, M. (2023). Investigating the implications of technological innovations, financial inclusion, and renewable energy in diminishing ecological footprints levels in emerging economies. Geoscience Frontiers, 14(6), 101667. https://doi.org/10.3389/fenvs.2021.744781

Silaghi, M. P., & Medeşfãlean, R. (2014). Some insights about determinants of economic growth in Romania. An empirical exercise. Theoretical and Applied Economics, 18(6), 23-36.

Solow, R. M. (1956). A contribution to the theory of economic growth. The quarterly journal of economics, 70(1), 65-94. https://doi.org/10.2307/1884513

Stojkoski, V., & Kocarev, L. (2017). The relationship between growth and economic complexity: evidence from Southeastern and Central Europe. https://mpra.ub.uni-muenchen.de/77837/

The Growth Lab at Harvard University. (2019). "Growth Projections and Complexity Rankings, V2" [Data set]. https://doi.org/10.7910/dvn/xtaqmc

Tsurumi, T., & Managi, S. (2014). The effect of trade openness on deforestation: empirical analysis for 142 countries. Environmental Economics and Policy Studies, 16, 305-324.
DOI 10.1007/s10018-012-0051-5

United Nations Development Program (UNDP). (2024). Human Development

Composite Indexes and Components Time Series. https://hdr.undp.org/sites/default/files/2023-24_HDR/HDR23-24_Composite_indices_complete_time_series.csv

World Bank. (2024). Data Bank. https://databank.worldbank.org/home.aspx

Wilson, D., & Purushothaman, R. (2003). Dreaming with BRICs: The path to 2050 (Vol. 99, pp. 1-23). New York: Goldman, Sachs & Company. https://ideas.repec.org/h/elg/eechap/3988_1.html

Yarygina, I., & Krylova, L. (2023). BRICS investment policy in contemporary environment. BRICS Journal of Economics, 4(2), 193-208. DOI 10.3897/brics-econ.4.e99251

Zafar, K. M. (2020). ARDL–Analysis of the Relationship among Exports, FDI, Current Account Deficit and Economic Growth in Pakistan. Iranian Economic Review, 24(2), 393-414. 10.22059/ier.2020.76010