Moderating Effects of Institutions and Economic Complexity on Green Growth

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ABSTRACT

In recent years, there has been a steady increase in environmental degradation, which has emerged as the primary cause of climatic variations. As a result, policymakers and researchers are investigating the factors that influence environmental quality. Previous studies have provided limited information on the effects of the interaction of globalization with economic complexity and institutions on the ecological footprint of 34 countries that are part of the Belt and Road Initiative (BRI). Therefore, this research aims to fill this gap by examining the factors mentioned above and their impact on the ecological footprint of the BRI countries. For empirical analysis, we used the two-step system generalized method of moments (GMM) that may address the endogeneity problem by orthogonal transformation and make the estimators more robust than the difference GMM. According to the findings of this research, globalization has a notable, beneficial impact after its interaction with economic complexity and institutions on the ecological footprint. In contrast, economic complexity alone, economic growth, and urban population have significant and positive effects on the environment. Institutions alone negatively affect the environmental footprint of the BRI countries. These conclusions offer valuable insights about the role of globalization, institutions, and economic complexity in promoting sustainable environmental development among the BRI participating nations. Additionally, this research provides a valuable reference point for ensuring ecological safety in other countries worldwide. The study may also shed light on important insights that policymakers and practitioners should consider while pursuing sustainable development policies.

Keywords: Institutional quality, Economic complexity, Globalization, Ecological footprint and BRI countries.

JEL Classification Codes: O44, O47, O34

1. INTRODUCTION

The advent of climate change has presented a host of difficulties for humanity's advancement and preservation, including extreme weather conditions, food scarcity, and environmental degradation (Chishti & Sinha, 2022). In December 2015, there was a consensus among the participants of the Paris Agreement about the gravity of the escalation of worldwide carbon emissions and temperatures (Pachauri et al., 2014). In 2013, President Xi Jinping of China announced the launch of the One Belt One Road (OBOR) project, an initiative to establish new institutional ties and trade networks across Asia, Europe, Africa, and the Middle East. The OBOR project aims to foster regional cooperation and coordinate economic policies, all while extending the historic legacy of the Silk Road. The initiative comprises several large-scale programs, including the Silk Road Economic Belt (SREB) and the Maritime Silk Road (MSR), both introduced by President Xi Jinping.

The OBOR seeks to connect the Baltic and Pacific oceans by utilizing sea lanes, roads, and railways to facilitate free trade. With a focus on shared economic interests, the OBOR has the potential to revolutionize the economies of China and its partner countries. The project encompasses over 65 economies, which account for roughly 80% of the global population and has an estimated budget of $21.1 trillion (Hafeez et al., 2019; Klinger, 2020).

Yilanci and Pata (2020) have also examined the Environmental Kuznets Curve (EKC) hypothesis, particularly for the case of China, and have further highlighted that increasing economic complexity may significantly contribute to reducing the ecological footprint. Okombi and Lebomoyi (2024) have also found that economic complexity may positively influence inclusive green growth (IGG), with public expenditure on education playing a crucial moderating role in this relationship.

Achieving harmony between environmental and economic objectives may also be a significant obstacle for economies in both developed and developing nations. The extensive growth of economies worldwide has facilitated the establishment of essential infrastructure, the alleviation of poverty/ reduction in income inequalities, and the enhancement of living standards for citizens. Nevertheless, this has come at a cost to natural resources, as exemplified by the depletion of land, loss of biodiversity, excessive exploitation of energy resources, and air and water pollution. These practices have compromised the global natural capital in pursuing rapid economic development as indicated by Alvarado et al. (2021). The fragility of societal structures, the depletion of ecological resources on the planet, and the increasing utilization of energy resources are currently being interconnected. Energy consumption and the production of goods are estimated to contribute 25% of the global pollution emissions (Shahbaz et al., 2022). Consequently, failing to achieve the Sustainable Development Goals (SDGs) will result in an enormous ecological deficit, making it impossible to attain the objective of sustainable societies and pollution reduction targets.

According to projections, global energy consumption is expected to increase by 82% from 2008 to 2035, while energy demand will rise by approximately 78% from 2010-2040, due to a surge in commercial transportation usage. This growth in energy consumption will lead to increased pollutants and greenhouse gas emissions in the atmosphere. Studies estimate that 25% of CO2 emissions will come from the transportation sector due to fuel combustion, with an expected annual increase of 1.7% in CO2 emissions by 2030. Developing countries are predicted to contribute nearly 80% of the increase in CO_2 emissions from land transport. Meanwhile, commercial cargo and international transport are forecasted to contribute only 3.9% of CO_2 emissions by 2050 (Chi & Baek, 2013; Kveiborg & Fosgerau, 2004; Nasreen et al., 2018).

In the 1960s, developed countries emitted more than 70% of the world's CO_2 (Brandon, 1994; Ekins, 1997). Industries emit 37% of greenhouse gases, with 80% of this resulting from energy consumption. The excessive use of fossil fuels may also reduce natural reserves, affecting environmental quality and climate change. Using alternative energy sources such as geothermal, solar, wind, and biomass energy is essential to reduce greenhouse gas emissions and other atmospheric pollutants. These alternative energy sources can be utilized domestically and commercially (Worrell et al., 2009).

Many funds allocated towards energy generation in the Belt and Road countries have been dedicated to coal-based projects, with only a tiny percentage directed towards wind-based energy generation. Notably, China was responsible for 40%

of global public investment in coal-based projects in 2007-2013 and has invested in 240 coal-based plants across 25 partner countries in the OBOR project, with a combined installed capacity of 251 gigawatts. Moreover, several Chinese firms plan to set up an additional 92 coal-based power projects in 27 different economies. Because of these developments, the CO2 emissions of the partner countries in the OBOR project, including China, have increased by 61.4%. The energy sector is a major contributor to environmental degradation in partner countries of the OBOR project, accounting for roughly 80% of CO2 emissions. While OBOR projects could lead to economic growth in these nations, it is worth noting that this growth may adversely affect the environment. This has been further emphasized by sources such as Global Capital (2017) and the Statistical Review of World Energy (2019). Many funds allocated towards energy generation in the Belt and Road countries have been dedicated to coal-based projects, with only a small percentage directed towards wind-based energy generation.

Notably, China was responsible for 40% of global public investment in coal-based projects between 2007–2013 and has invested in 240 coal-based plants across 25 partner countries in the OBOR project, with a combined installed capacity of 251 gigawatts. Moreover, several Chinese firms plan to set up an additional 92 coal-based power projects in 27 different economies. Because of these developments, the CO_2 emissions of the partner countries in the OBOR project, including China, have increased by 61.4%.

The energy sector is a major contributor to environmental degradation in partner countries of the OBOR project, accounting for roughly 80% of CO_2 emissions. While OBOR projects could lead to economic growth in these nations, it is worth noting that this growth may adversely affect the environment. This has been further emphasized by sources such as Global Capital (2017) and the Statistical Review of World Energy (2019).

Carbon dioxide is often used as a proxy in environmental risk studies since it constitutes the most significant portion of greenhouse gases (Kamal et al., 2021). However, some scholars argue that carbon emissions do not account for the entirety of the ecosystem and may not fully capture environmental contamination (Nathaniel & Khan, 2020). For example, they contend that CO_2 emissions cannot predict the availability of resources like petroleum gas, forests, soil, and oil. Policymakers and other decision-makers require a proxy that provides a more comprehensive view of environmental sustainability. The ecological footprint is one of the most widely accepted indicators of environmental quality and can be used to manage and evaluate natural resources (Khan et al., 2021). It measures how quickly humans consume resources and generate waste and how fast nature can absorb these activities. The ecological footprint encompasses "the impact of human activities measured in terms of the biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated" (Saud et al., 2020). It also determines human demand for natural capital and can be compared at individual, regional, and global levels. Renewable resources are the primary focus of ecological footprints.

In this paper, we have explicitly attempted to fill a gap in existing literature by examining the impact of the interaction terms (moderating effects) of globalization, economic complexity, and institutions on the ecological footprint in the specific case of BRI countries. However, previous literature has provided scant information on these specific moderating/interaction effects.

The study utilizes the two-step system generalized method of moments (GMM) for its empirical analysis; this approach is specifically chosen to "curb the endogeneity issues by orthogonal transformation," particularly those that may emerge due to theoretical endogeneity associated with institutions. The two-step system GMM is preferred over the difference GMM because it provides "more robust estimators." For small sample sizes, the two-step system GMM estimators are less prone to significant downward bias; moreover, the Wald test is even more powerful. This ensures the reliability and validity of the study's findings, especially given the panel data structure comprising 33 BRI countries.

1.1. Aim of the study

This study aims to examine the impact of the interaction between globalization, institutions, and economic complexity on the ecological footprint of Belt and Road Initiative (BRI) countries.

1.2. Significance of Study

This study distinguishes itself from previous research in several ways.

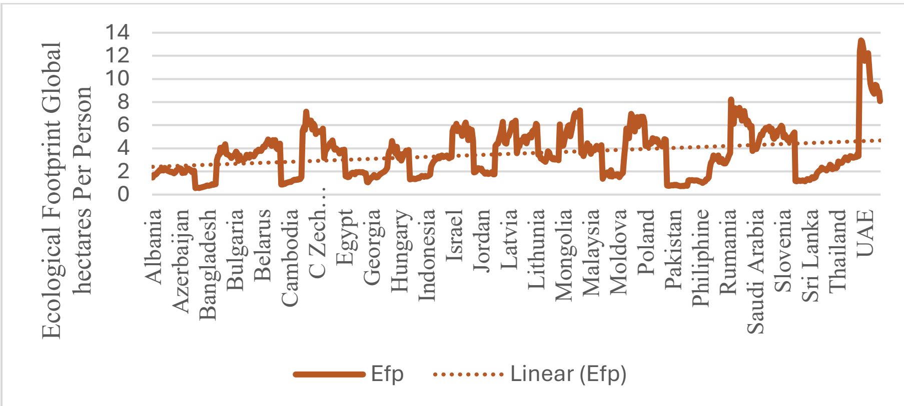
Firstly, it examines the impact of the interaction terms of institutions and economic complexity with globalization on the ecological footprint in all 33 members of the BRI from 2000 to 2020, making it the first of its kind.

The findings of this study provide valuable insights for governments, policymakers, and the public to develop better policies and understand the environmental consequences of these factors.

2. CONTEXTUAL AND DESCRIPTIVE ANALYSIS

The process of globalization involves removing barriers to the flow of goods, services, and capital, which can lead to economic growth by facilitating trade, foreign direct investment, technology transfer, and the more efficient use of resources (Pata & Caglar, 2021). While earlier studies have extensively explored the impact of globalization on environmental sustainability; there is still no consensus on the exact relationship between the two. Some studies suggest that globalization positively affects environmental performance, while others argue it has adverse effects.

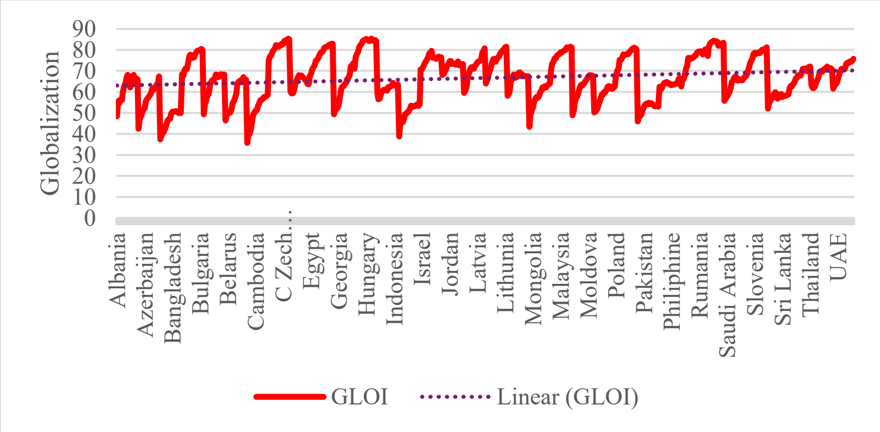
Figure 1: Ecological footprint in Belt and Road Initiative Economies



Source: Developed by authors.

As growth often requires increased energy consumption, it is important to understand the interplay between globalization, economic growth, and the ecological footprint (Wang et al., 2020; Saud et al., 2020; Saint Akadiri et al., 2019). In this regard, the current study aims to investigate the impact of globalization and ecological footprint on the economies participating in the BRI.

Figure 2: Globalization in Belt and Road Initiative Economies

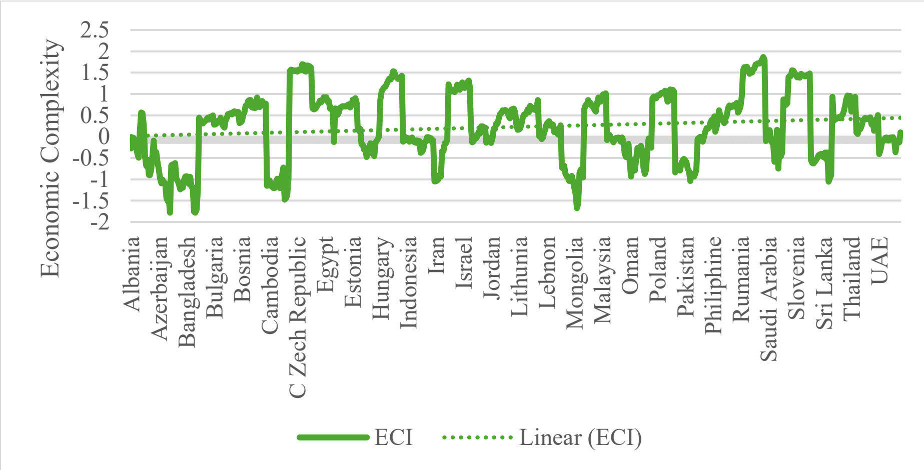


Source: Developed by authors.

Economic complexity is a crucial factor in this study, encompassing various production-related elements, including development, knowledge, and competencies (Hausmann et al., 2014). The Economic Complexity Index (ECI) is a reliable and accurate measure of growth, and it has gained attention from environmental and social scientists in the current economic context (Hausmann & Hidalgo, 2011).

The ECI further enhances production diversity, accelerates future investments, and increases energy consumption and pollution. However, economic complexity appears to be a more sustainable option for the environment as it emphasizes research and development, machinery and equipment, and utilizes cleaner, greener, and renewable technologies and more eco-friendly products (Neagu & Teodoru, 2019). Manufacturing complex products results in higher energy consumption, which is met through various sources such as fossil fuels, nuclear, and renewable energy. A country's production structure significantly impacts the environment as the level of complexity of products may lead to pollution generation and natural resource consumption. The ECI may assess a country's capacity to produce and export complex products and estimates the productive knowledge level. A higher ECI value indicates a country's more significant potential for production and exporting higher value-added or more complex products. Therefore, this study contributes significantly to the literature on ecological footprints.

Figure 3: Economic complexity in Belt and Road Initiative Economies



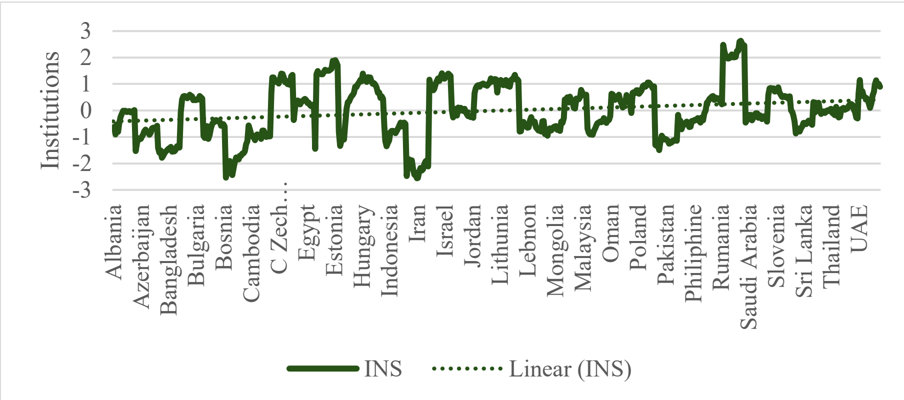
Source: Developed by authors.

There is a wealth of evidence indicating that countries with robust institutional frameworks tend to be more effective in mitigating environmental challenges such as greenhouse gas emissions, climate change, and environmental degradation (Ahmed et al., 2020; Dees, 2020; Ibrahim & Law, 2016; Khan & Rana, 2021; Ntow-Gyamfi et al., 2020; Sah, 2021). Institutional quality plays a critical role in advocating for sustainable development. Improving institutional performance is essential for controlling and reducing harmful emissions during economic development (Hunjra et al., 2020; Lau et al., 2014).

Importantly, enhancing institutional capacity is a key factor in promoting environmental sustainability and reducing the negative impact of human activities on the planet. According to a recent study, the quality of a country's institutions can have a detrimental effect on the growth of per capita CO_2 emissions and lead to environmental degradation (Islam et al., 2021; Runar et al., 2017).

Institutional performance is also critical in the relationship between foreign direct investment and pollutants. Climate change can lower productivity growth, but effective institutional frameworks can help developing countries mitigate its negative impacts by regulating the process of technology adoption (Kumar & Managi, 2016). Therefore, it is essential to strengthen institutions through appropriate regulations, laws, property rights, and corruption control to facilitate more efficient and effective practices that can help reduce pollutant emissions (Ali et al., 2019).

Figure 4: Institutions in Belt and Road Initiative Economies



Source: Developed by authors.

The decision to focus on BRI countries in this study is justified for several compelling reasons. According to a report from China, the BRI initiative will involve the participation of 65 nations, including 24 from Europe, 15 from North Africa and the Middle East, and 26 from Asia Hassan, Xia, Khan, and Shah (2019). This makes the BRI a significant and wide-ranging initiative with global implications, highlighting the importance of understanding its impact on participating countries. The BRI project is a massive undertaking that encompasses 30% of the world's GDP and directly impacts the lives of 4.4 billion individuals. The BRI could transform the global economy, with 65 countries participating and 48 more expressing interest. In 2017, the State Information Center reported that 71 nations had joined the initiative, and an impressive USD 6 trillion had been invested, equivalent to 34% of global GDP (Suki et al., 2020).

However, despite these significant investments, many BRI countries have struggled to modernize their industrial activities, resulting in increased reliance on fossil fuels and a subsequent rise in global warming (Kang et al., 2016). This highlights the need to address the environmental impact of the BRI project while promoting its economic potential. The BRI project's impact is too significant to ignore, and understanding its implications is essential for policymakers and stakeholders alike. Since its launch in 2013, China has invested USD 760–13,824 billion in the BRI project, with around 39% of these funds allocated to the energy sector, 26% to transportation, and 7% to metals.

The BRI countries also play a significant role in global natural resource production, being responsible for 74.69% of coal, 53.82% of natural gas, and 55.17% of known crude oil reserves (Hussain et al., 2020). With a population representing 62% of the world's total, these nations contribute nearly 31% of global GDP and 35% of global trade (Baloch et al., 2019). However, it is concerning that this project may also be responsible for 28% of global carbon emissions and could contribute to a 2°C increase in global temperature if development continues as planned, potentially leading to a 66% increase in carbon emissions by 2050. The economies associated with the Belt and Road Initiative (BRI) hold significant economic influence due to their global interconnections and strong economic ties (Khan et al., 2020).

3. LITERATURE REVIEW

The relationship between economic development and income inequality has been extensively studied in this section. Kuznets' (1955) work proposes that income inequality initially increases during the early stages of economic development but then decreases as economic growth continues, forming an inverted U-shaped curve.

Another notable study by Grossman and Krueger (1995) extended this idea to the relationship between pollution and GDP per capita, showing an inverted U-shaped curve, commonly known as the Environmental Kuznets Curve (EKC) hypothesis. This important hypothesis has since been widely used in theoretical and empirical research to explore the link between environmental degradation and GDP per capita in developing countries.

The literature collectively highlights the complex interplay between industrialization, economic growth, and environmental degradation, particularly in the context of rising carbon dioxide (CO_2) emissions. Chang and Lin (1999) and Chaitanya (2007) underscore the detrimental environmental impacts of industrialization in both Taiwan and developed countries, with Tunç et al. (2009) further emphasizing the role of industrial expansion as a primary driver of CO_2 emissions in Turkey.

Similarly, Shahbaz et al. (2014) note that while industrial growth initially exacerbates environmental degradation in Bangladesh, a threshold exists beyond which further expansion does not worsen environmental conditions. This contrasts with findings from Malaysia by Lau, Cummins, and McPherson (2005), who argue that institutional quality can mitigate CO_2 emissions while fostering economic growth, a perspective supported by Al-Mulali and Ozturk (2015) and Ibrahim and Law (2016).

These studies suggest that while industrialization significantly contributes to environmental decline, institutional frameworks and policy interventions can play a pivotal role in reconciling economic development with environmental sustainability. The role of renewable energy and economic complexity in shaping environmental outcomes is another critical theme emerging from the literature. Adebayo et al. (2022) and Kirikkaleli and Adebayo (2021) demonstrate that renewable energy consumption and public-private investments in energy can significantly reduce CO_2 emissions.

However, the relationship between economic growth and environmental quality varies across regions. For instance, Adebayo et al. (2022) find that political instability and internationalization exacerbate environmental degradation in BRICS countries, while also highlighting the positive environmental impacts of globalization and renewable energy in newly industrialized countries. These findings are consistent with the EKC hypothesis, as evidenced by Gyamfi et al. (2022) in the Mediterranean region. Meanwhile, Altıntaş and Kassouri (2020) and Narayan et al. (2016) challenge the universality of the EKC, suggesting that its applicability varies depending on regional economic conditions.

Similarly, Javid and Sharif (2016) and Rehman and Rashid (2017) emphasize the role of energy consumption and financial development in driving CO_2 emissions in Pakistan and SAARC countries, respectively. These studies reveal that renewable energy and institutional quality offer important pathways to sustainable development and that the relationship between economic growth and environmental degradation remains highly context specific.

Environmental deterioration has increased over the years and is now the main reason for climate change. Researchers and policymakers are investigating the factors that affect environmental quality, particularly in countries involved in the Belt and Road Initiative (BRI).

This study aims to fill this gap in literature by examining the impact of the interaction terms of globalization with economic complexity and institutions on the ecological footprint in BRI countries from 2000 to 2020. The study uses the two-step system GMM method to analyze the data. It provides important insights into sustainable development in BRI countries and offers valuable guidance for policymakers and practitioners.

4. METHODOLOGY

4.1. Data and Model

In this research, the ecological footprint of economies involved in the Belt and Road Initiative has been examined from the years 2000 to 2020, with a focus on how the interaction of economic complexity and institutions with globalization has impacted it. The sample size of the study is bound to the availability of data. The ecological footprint is a measure of the overall impact of the production and consumption of commodities on the environment. It has gained popularity as an indicator of environmental pollution because it takes into account both direct and indirect impacts of production and energy consumption. For estimation of the empirical inferences in this study, the functional form of the economic models is used as follows:

$$ECFT = f(INS, ECI, GLOB, ,PCY, GLOBECI,UP) \quad (1)$$

$$ECFT = f(INS, GLOB, ,PCY, GLOBINS,PS) \quad (2)$$

In the above equations (1) and (2), INS, ECI, GLOB, PCY, GLOBECI, UP, PS, and GLOBINS represent the ecological footprint, economic complexity Index, globalization per capita income, interaction term of globalization and economic complexity, urban population, interaction term of globalization and institutions and public spending respectively.

Effective environmental policies require strong and efficient institutions in any country. The presence of such institutions ensures that the government can enforce environmental regulations properly. In countries where institutional quality is poor, companies that prioritize profit over sustainability may resort to bribing officials to use machinery and technology that contribute to environmental pollution (McCormack & Edwards, 2011).

The level of economic complexity in countries participating in the Belt and Road Initiative (BRI) has been found to contribute to a 0.092% increase in their ecological footprint. This finding aligns with previous studies conducted on the G-7 economies, the United States, and EU economies, which have shown that greater economic complexity results in a higher risk of greenhouse gas emissions and a larger ecological footprint (Khan et al., 2020; Neagu & Teodoru, 2019; Pata, 2021; Qian & Madni, 2022). These countries prioritize the production of sophisticated and valuable goods, often at the expense of the environment, leading to the misuse of natural resources and greater reliance on nonrenewable energy sources. As a result, the environment in BRI countries is adversely affected by the current technology and energy consumption patterns.

Globalization is often linked with negative impacts on the environment, particularly the pollution of land, water, and air resulting from increased transportation, production, and energy consumption. Critics argue that globalization may incentivize polluting companies and increase ecological demands in countries with less stringent environmental regulations (Jahanger, 2022). Thus, by taking into account the potential environmental impacts of globalization and adopting a proactive approach to implementing necessary reforms, it is possible to achieve economic growth while minimizing ecological harm (Pata & Yilanci, 2020).

The functional form of equations (1), and (2), may now be written as

$$ECFT_{it} = \alpha_0 + \alpha_1 ECFT_{it-1} + \alpha_2 ECI + \alpha_3 GLOB_{it} + \alpha_4 GLOB*ECI_{it} + \alpha_5 UP + \alpha_6 PCY + e_{it} \quad (3)$$

$$ECFT_{it} = \alpha_0 + \alpha_1 ECFT_{it-1} + \alpha_2 INS_{it} + \alpha_3 GLOB_{it} + \alpha_4 GLOB*INS_{it} + \alpha_5 PS + e_{it} \quad (4)$$

Table 1: Information about Variables

Variables Source	Symbols	Measurements	Sources	Source Link
Ecological Footprint	ECFT	Global hectares Per Person	Global Footprint Network	https://www.footprintnetwork.org/
Globalization	GLOB	KOF (Konjunkturforschungsstelle) Index	KOF Swiss Economic Institute	https://kof.ethz.ch/en/
Institutions	INS	Institutional index	World Governance Indicators	https://databank.worldbank.org/
Economic Complexity	ECI	Economic Complexity Index	Atlas of Economic Complexity	https://atlas.cid.harvard.edu
Urban Population	UP	Urban Population as a Percentage of Total Population	World Development Indicators	World Development Indicators | DataBank (worldbank.org)
GDP Per Capita	PCY	GDP Per Capita (Constant 2015 US$)	World Development Indicators	World Development Indicators | DataBank (worldbank.org)
The Interaction term of Globalization and Economic Complexity	GLOBECI	KOF (Konjunkturforschungsstelle) Index, (Economic Complexity Index)	KOF Swiss Economic Institute, (Atlas of Economic Complexity)	https://kof.ethz.ch/en/ https://atlas.cid.harvard.edu
Public Spending	PS	Total general expenditures of government	World Development Indicators	World Development Indicators | DataBank (worldbank.org)
The Interaction term of Globalization and Institutions	GLOBINS	KOF (Konjunkturforschungsstelle) Index, (Institutional Index)	KOF Swiss Economic Institute, (World Governance Indicators)	https://databank.worldbank.org/ https://kof.ethz.ch/en/

Source: Developed by authors.

4.2. Econometric Strategy: The Generalized Method of Moments (GMM)

Endogeneity plays a crucial part in fabricating bias in the estimators of traditional econometric tools. To address the problem of simultaneity and obtain unbiased results, Hansen (1982) developed the Generalized Method of Moments (GMM), which does not require full knowledge of data distribution. The GMM method is a fruitful method that can be used often for the curtailing of endogeneity and heteroscedasticity. GMM is especially useful in addressing endogeneity and heteroscedasticity. The GMM estimators proposed by Arellano and Bover (1995) and Blundell and Bond (1998) are particularly suited for small-sample panels where the number of cross-sections exceeds the number of periods.

Suppose we have an econometric model equation:

$$M = R'\beta + \epsilon \tag{5}$$

where the error term does not depend on instrument variables $EE(II) = 0$. β is the coefficient vector. M is the dependent variable, and R denotes the column vector of k independent variables, $R = (r1, r2, \ldots rk)'$. I show the column vector of j instrument variables, $I = (i1, i2, \ldots iijj)'$. R and I can share their variables because the moments of the independent variables can be used as instruments and j ≥ k. R, M, and I are the matrices, and r, m, and i are the variables. E = M-Rβ and the estimated residuals are $\widehat{Z} = (\hat{z}_1, \hat{z}_2, \hat{z}_n)'$, which can be written as $\hat{Z} = (\hat{z}_1, \hat{z}_2, \hat{z}_n)' = M\text{-}R\hat{\beta}$. The necessary condition for the instruments to be valid is the orthogonality of the instrument to the residuals, Z (z,) = 0. Theoretically and empirically, $Z_N(Iz) = (\frac{1}{N}) I'\hat{Z}$.

In the generalized method of moments, the magnitude can be found through a generalized metric consisting of a positive semi-definite quadratic function. Suppose we have P, which is the matrix of that quadratic function. After that, the equation is written.

$$\|Z_N(I_Z)\|P = \|1/NI'\widehat{Z}\|P = N(\frac{1}{N}I'\widehat{Z})' P (\frac{1}{N}I'\widehat{Z}) = \frac{1}{N}\widehat{Z}` IPI` \hat{Z} \tag{6}$$

To get the choice vector of coefficients β_P, there is a need to minimize $\beta_P = argmin\,\hat{\beta}\ \|I'\hat{Z}\|Q$, so, β_P can be derived with the help of $d/d(\hat{\beta})\|I' Z\|P = 0$. By following the chain rule of derivatives, this equation can be explored as set out below

$$0 = \frac{d}{d(\hat{\beta})\|I'\hat{Z}\|P} = \frac{\mathrm{d}}{\mathrm{d}(\hat{Z})}\|I'\hat{Z}\|P\frac{\mathrm{d}\hat{Z}}{\mathrm{d}(\hat{\beta})} \tag{7}$$

$$0 = \frac{\frac{\mathrm{d}}{\mathrm{d}(\hat{Z})}\{\frac{1}{N}\hat{Z}(IPI`)Id(M-R\hat{\beta})}{d\hat{\beta}} = \frac{2}{N}\hat{Z}\,IPI`(\text{-X}) \tag{8}$$

After dropping the -2/N and taking the transpose, equation 4 becomes:

$$0 = \widehat{Z`}\, IPI`R = (M - \widehat{\beta}_P)`\, IPI`R = M'\, IPI`R - \widehat{\beta`}_P\, R`IPI`R \quad (9)$$

$$R`IPI`R\,\widehat{\beta`}_P = R`IPI`M \quad (10)$$

Equation 9 will become:

$$\widehat{\beta`}_P = \frac{R`IPI`M}{R`IPI`R} = (R`IPI`R)^{-1}\, R`IPI`M \quad (11)$$

Efficient instruments should be present within the model, so we can get these instruments only by using internal instruments. So, the dynamic[i] model in its general form will be:

$$m_{it} = \gamma m_{i,t-1} + R'_{it}\,\beta + z_{it} \quad (12)$$

Where $z_{it} = \vartheta_{it} + \omega_{it}$, and may also , $Z(\vartheta_{it}) = Z(\omega_{it}) = Z(\omega_{it}, \vartheta_{it}) = 0$. The error term has two orthogonal parts. The first one is the fixed part ϑi while the second part ω_{it} is idiosyncratic shocks. So, we can write the equation as

$$\Delta m_{it} = (\gamma - 1)m_{i,t-1} + R'_{it}\,\beta + \varepsilon_{it} \quad (13)$$

5. EMPIRICAL FINDINGS AND DESCRIPTION

The validity and reliability of the estimators in this study heavily depend on the choice of econometric techniques, which must be tailored to match the specific characteristics and patterns of the data. Failure to select the appropriate technique can introduce bias and make the estimators untrustworthy.

To carry out this study, we employed the two-step system GMM (SYS-GMM) estimators originally devised by Arellano and Bover (1995) and later refined by Blundell and Bond (1998). Researchers have noted that for small sample sizes, the two-step SYS-GMM estimators are prone to significant downward bias; however, the Wald test based on two-step SYS-GMM is more powerful than that based on the one-step version (Windmeijer, 2005). Hence, for this research, we have opted to report the results obtained using the two-step SYS-GMM estimator, in accordance with Windmeijer's recommendations.

Table 2: Two-Step System GMM results for Equation 3

Variable	Coefficient	Std. Error	Z-Statistics	Prob
Ecological Footprint (Lagged)	0.826	0.0074	111.6	0.000
Economic Complexity	0.299	0.093	3.20	0.001
Globalization	-0.000	0.0015	-0.12	0.905
Urban Population	0.007	0.000	8.23	0.000
Globalization* Economic Complexity	-0.005	0.001	-3.53	0.000
Per Capita Income	0.000	0.000	38.33	0.000
Constant	-0.046	0.116	-0.40	0.688
Number of observations	611			
Number of countries	34			
Wald $\chi 2$ value	182000			
Prob > $\chi 2$	0.0000			
Arellano–Bond test for AR(1) in differences (p values)	0.001			
Arellano–Bond test for AR(1) in differences (p values)	0.318			
Hansen test of joint validity of instruments (p-value)	1.000			

Source: Developed by authors.

The results in Table 2 (for Equation 3) show the impact of the lagged ecological footprint, economic complexity, globalization, urban population, the interaction term of globalization and economic complexity, and per capita income on ecological footprint. The lagged ecological footprint shows a strong positive and significant association, confirming path dependence in ecological pressure.

Economic complexity has a positive and significant impact (at the 5% level), suggesting that more complex economies, while technologically advanced, often exert greater pressure on ecological systems. This finding is aligned with the conclusions of Khan et al. (2020), Neagu and Teodoru (2019), and Pata (2021). These scholars argue that economic complexity contributes to increased greenhouse gas emissions and environmental harm because countries tend to produce more sophisticated, high-value products that require intensive use of energy and nonrenewable resources. As the global demand for such products rises, the environmental burden worsens.

The urban population also has a positive and significant relationship (at the 1% level) with the ecological footprint. This result is consistent with Muñoz et al. (2020), who show that urbanization intensifies environmental degradation through rising consumption, mobility demands, and infrastructural strain. Per capita income, serving as a proxy for economic growth, is also positively and significantly associated with the ecological footprint at the 1% level. This supports earlier studies such as Madni (2022) and Yilanci and Pata (2020), who highlight that income growth often leads to increased resource use and emissions.

Table 3: Two-Step System GMM Results for Equation 4

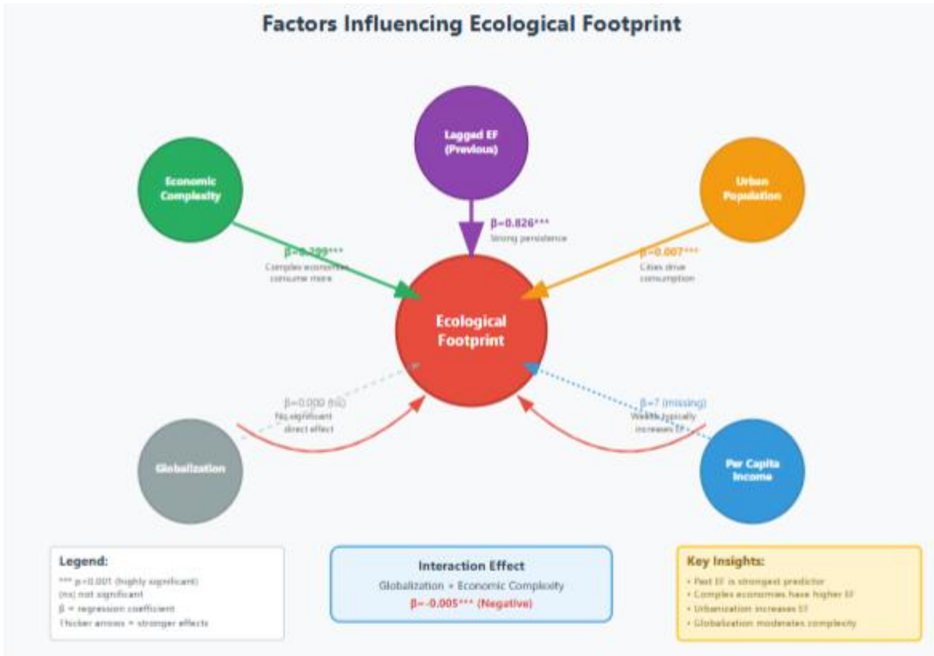
Variable	Coefficient	Std. Error	Z-Statistic	Prob.
Ecological Footprint (Lagged)	0.852	0.0074	113.92	0.0000
Institutions	-0.440	0.1031	-4.27	0.0000
Globalization	-0.001	0.0011	-1.80	0.280
Globalizations* Institutions	-0.006	0.001	-4.94	0.0000
Public Spending	-0.000	0.0000	-1.06	0.288
Per Capita Income	0.0000	0.0000	33.53	0.0000
Constant	0.395	0.0727	5.43	0.000
Number of observations	611			
Number of countries	34			
Wald $\chi 2$ value	53756.29			
Prob $>\chi 2$	0.0000			
Arellano–Bond test for AR(1) in diferences (p values)	0.001			
Arellano–Bond test for AR(1) in diferences (p values)	0.312			
Hansen test of joint validity of instruments (p-value)	1.000			

Source: Developed by authors.

Interestingly, globalization on its own has a statistically insignificant negative impact on ecological footprint. However, the interaction term (Globalization × Economic Complexity) becomes negative and statistically significant, suggesting that when globalization is accompanied by high economic complexity, it can actually reduce environmental harm. This reflects a key contribution of this study: economic complexity can act as a critical moderator in the globalization–environment nexus, transforming globalization's environmental effects from harmful to potentially beneficial.

The empirical findings of Table 3 for equation 4 elucidate that the lagged variable of ecological footprint has a positive impact on ecological footprint (See figure 4).

Figure 4: Conceptual Linkages and Explanations



Source: Developed by the author.

Institutions have a negative and significant impact on the ecological footprint at the 1% level of significance. This suggests that stronger institutional frameworks are effective in reducing environmental degradation. These results are consistent with prior studies by McCormack and Edwards (2011) and Wu and Madni (2021).

Economic growth also has a positive and statistically significant relationship with the ecological footprint at the 1% level, as illustrated in Figure 4. This finding aligns with prior empirical evidence presented in Langnel and Amegavi (2020), Qian and Madni (2022), and Yilanci and Pata (2020), all of which emphasize the environmental cost of economic expansion.

While globalization alone shows a negative but statistically insignificant effect on the ecological footprint, its interaction with institutional quality becomes negatively significant at the 1% level. This indicates that institutional strength moderates the adverse effects of globalization, helping to reduce environmental harm when governance structures are robust.

This finding also represents a key contribution of the present study to the existing literature on ecological footprints, particularly by emphasizing the moderating role of institutional quality in the globalization–environment relationship.

6. CONCLUSION

Over the past few decades, environmental degradation has escalated, becoming one of the primary concerns of this century. This has led researchers and policymakers to examine the key factors that affect environmental quality.

In this context, the present study has made a notable contribution by investigating the impact of globalization, economic complexity, and institutional quality, both individually and through their interactions, on the ecological footprint in 33 BRI countries over the period 2000 to 2020.

Using the two-step system GMM estimator, the findings reveal that economic growth and urbanization exert a statistically significant and positive impact on ecological footprints, suggesting that rising income and population concentration contribute to environmental degradation.

In contrast, strong institutional quality has a significant negative effect, confirming that robust governance can help reduce environmental harm.

Moreover, the study demonstrates that globalization alone does not significantly affect ecological footprints, but its interaction with economic complexity and institutional quality reveals significant moderating effects. Specifically, these interactions lead to a reduction in the ecological footprint, implying that economic complexity and strong institutions can transform globalization from an environmental threat into a sustainable growth pathway.

These findings not only fill a gap in literature but also offer valuable guidance for policymakers in BRI and other developing countries on designing integrated policy strategies that promote sustainable development.

The study recommends the promotion of economic complexity through investment in R&D and innovation, as well as strengthening institutional frameworks to enhance environmental governance. Such measures can help mitigate the negative impacts of globalization and economic growth on the environment, thereby fostering long-term ecological sustainability.

7. POLICY IMPLICATIONS

Based on the findings of this study, several evidence-based policy recommendations can be proposed to promote environmental sustainability in Belt and Road Initiative (BRI) countries.

First, governments should strengthen institutional frameworks by enforcing effective regulatory systems, rule of law, anti-corruption measures, and transparent governance practices. A well-functioning institutional setup is essential to mitigate the environmental consequences of globalization and industrial expansion.

Second, BRI countries should invest in economic complexity by promoting research and development (R&D), technological innovation, and education. This will enable countries to transition toward the production of high-value, energy-efficient, and environmentally friendly goods, ultimately reducing their ecological footprint.

Third, while globalization alone does not significantly impact ecological degradation, its interaction with economic complexity and institutions reveals its potential as a driver of sustainable development. Therefore, policy efforts should focus on managing globalization through environmental standards, cross-border sustainability frameworks, and regional cooperation.

Fourth, urban planning and infrastructure development should be guided by sustainability principles. The positive correlation between urbanization and ecological footprint suggests that energy-efficient transportation systems, waste management, green architecture, and renewable energy integration in urban settings are critical to minimizing ecological stress.

Finally, governments must adopt comprehensive fiscal strategies to ensure that public spending is directed toward sustainable sectors, such as clean energy, environmental protection, and climate-resilient infrastructure. Redirecting environmentally harmful subsidies and introducing green taxes may also support these goals.

In conclusion, BRI economies must adopt a multi-dimensional approach, combining institutional reforms, economic modernization, and globalization management, to align with the objectives of the Paris Agreement and the United Nations Sustainable Development Goals (SDGs).

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