Relationships between economic complexity, renewable energy uptake and environmental degradation: A global study

Abstract

A persistent rise in the emission of CO_2 among several economies in the world makes it challenging to fulfil the aims of sustainable development goals. The present study empirically examines the connection between economic complexity, which is understood to be structural conversion headed for more refined information-based production, renewable energy demand, per capita income, trade openness, industrialisation, and CO_2 emission among income-based groups of nations from 1998-2021. It also incorporates partner economies of the One Belt One Road (OBOR) project because it covers 65% of the global population. The study pioneers in economic complexity and renewable energy demand impact on the emission of CO_2 analysis globally, and it also segregates partner economies of OBOR because they are associated with the mega project, which helps to increase the economic growth by minimising the trade costs. The projected finding of the panel ARDL (autoregressive distributed lag) model confirms that virtually all chosen samples of various economies, aside from high-income economies, show that economic complexity degrades the environment. On the other hand, the demand for renewable energy enhances global environmental quality. The study implicates the significance of clean energy ventures and the production of greener quality products globally to minimise environmental damage.

Keywords: *economic complexity; One Belt One Road (OBOR); renewable energy demand; CO_2 emission.*

JEL Classification: C82; P18; Q19-20;

1. Introduction

It is widely acknowledged that specialisation and the division of labour are crucial components of a nation's wealth (Hidalgo and Hausmann, 2009). The variety and ubiquity of knowledge are correlated with economic complexity in a given economy. However, an idea that may derive from the concept of economic complexity is that economic output does not primarily depend upon the richness of labour or resources but also relies on the capabilities, knowledge, and productive capacities that may be embedded in the activities of the economy. In other words, it also emphasises what an economy may produce and how it produces it, and it is also subject to the web of skills, knowledge, and technology that may be relatively simple or highly complex. A nation's economy may become more complex when people from various industries collaborate and share information to create a broader range of products. Economic complexity is usually measured with the help of the economic complexity index (ECI). The ECI is a quantitative matrix that may reflect the sophistication and diversity of an economy’s exports (Hausmann and Hidalgo, 2011). Economic complexity is the term used to describe how production has changed structurally as it has shifted towards more technologically and knowledge-based production processes of the goods in the export basket[1]. It is vital to comprehend how a country’s economic complexity influences its material utilisation, resource efficiency, and connection to a clean environment because knowledge and human capital are the cornerstones of effective production from a sustainability standpoint. The Sustainable Development Goals (SDGs) are accomplished by doing more and better with less in order to increase resource efficiency through sustainable patterns of production and consumption (Lenzen et al., 2022; United Nations, 2015). The average level of sophistication of the goods that various nations can produce can be used to gauge economic complexity. The ECI has been particularly effective at illuminating the causes of Gross Domestic Product (GDP) per capita fluctuation of various nations. Additionally, it aids in forecasting economic expansion (Hidalgo et al., 2007; Hidalgo and Hausmann, 2009; Hausmann et al., 2014).

[1] Atlas Database: https://atlas.cid.harvard.edu/rankings

Economic complexity has grown in importance in the on-going global conversation over climate change in recent years. Experts on climate change concur that environmental deterioration is the cause of climate change. Understanding how to create operative climate change mitigation sequencers, it is essential to comprehend how economic complexity affects environmental deterioration (Romero and Gramkow, 2021; Abbasi et al., 2021; Zheng et al., 2021; Caglar et al., 2022). Environmental Kuznets curve theory (Grossman and Krueger, 1991) states that the environment gets worse as income or economic progress increases, which later improves. Economic complexity explains and predicts cross-country differences in income and economic progress trajectories (Hidalgo and Hausmann, 2009; Hidalgo, 2021). Consequently, strategies for achieving economic complexity could significantly impact environmental degradation.

Economic complexity's effect on carbon emissions is multifaceted and involves various factors and dynamics. Economically complex economies often have diverse and advanced industrial sectors, including manufacturing, services, and high-tech industries. These sectors may contribute to higher carbon emissions due to increased energy consumption, use of fossil fuels, and production of goods and services with high carbon footprints. Similarly, economic complexity may affect consumption patterns, including the goods and services demanded. In some cases, increased economic complexity may lead to a shift towards more resource-intensive and carbon intensive consumption patterns. For example, increasing income will result in a rise in the demand for energy intensive commodities, such as automobiles and air conditioning appliances, that are further degrading the environment (Hidalgo et al., 2007; Hidalgo and Hausmann, 2009; Minondo and Requena-Silvente, 2013). Stefanski (2015) investigates the relationship between fossil fuel subsidies and emission intensity patterns in a sample of 170 nations between 1980 and 2010. According to the study, industrialisation boosts emission levels up to a certain point at lower income levels. Industrialisation is linked to decreased emissions at higher income levels, demonstrating an inverted U-shaped connection. Contrary to the above discussion, the current study also incorporates One Belt One Road economies which may have a more diversified and complex structure and is more likely to have a mix of industries, including those that are less carbon intensive. Moreover, economies with strong technology and knowledge-based sectors may have lower carbon emissions when compared to those heavily reliant on manufacturing industry. Similarly, economic complexity also involves the transfer of knowledge and skills among One Belt One Road initiative economies. CO_2 emissions may also be reduced by the exchange of clean and efficient technologies among Belt and Road Initiative (BRI) economies (Naudé et al., 2013).

The Project of OBOR (One Belt One Road) and United Nations' Millennium Development Goals have similar grand objectives and both offer public goods around the globe. China introduced this project in early 2010. The OBOR venture includes 21st Century MSR (Maritime Silk Road) and SEB (Silk Road Economic Belt), which initiated the long-term economic cooperation among interconnect economies. OBOR is a worldwide collaboration platform and it has gained comprehensive attention from governments, enterprises, and academicians. This group accounts for 30% of global income with 60% of global population by integrating together many developing and developed economies into an inclusive and open collaborative network (Huang, 2016; Lam et al., 2018; Bai et al., 2019). The estimated project cost is $21.1 trillion USD, spanning 65 connected economies. Since the Greenhouse Gas (GHG) emission comparison between 1970 and 2022 also showed that there was a significant increase in emissions in China and India (Crippa et al. 2023), OBOR projects initiated structural changes in response to a sudden increase in GHG in this region as reported by Crippa et al. (2023). The economies partnered in OBOR, such as Brazil, China, India, and Russia, account for 0.94%, 11%, 3% and 3.80% of global emissions of CO_2 respectively. However, the CO_2 emanation was spread at 1.15% in Brazil, 16% in China, 5% in India, and 6% in Russia in 2007 (Hafeez et al., 2019; Klinger, 2019). In addition, whilst there are major CO_2 emissions in the United States of America, China, India, and Russia, it is estimated that India and China may contribute more in emissions with a share 8% and 11% because of their consistent high growths. The total human related ecological footprints comprise 60% of carbon footprints and remaining components are buildings, land, forest cultivation, product manufacturing, and grazing land (Hafeez et al., 2019). Moreover, many studies such as Ozcan et al. (2018), Danish et al. (2020), and Ahmed et al. (2020) suggest that ecological footprints preclude as an appropriate evaluation measure for the influence of human-created activities on environment.

The study primarily evaluates economic complexity, renewable energy demand, and CO_2 emission association globally among several economies, diversified by using levels of their income such as high-, upper-middle-, low-middle-, low-income, and partner economies of OBOR. Typically, energy-intensive businesses, power plants, and transportation-related industrial activities are the sources of CO_2 emissions. CO_2 emissions account for about 75% of the greenhouse gas emissions that are raising global temperatures (Abbasi and Riaz, 2016). This study incorporates modern literature in many ways. The current study pioneers in evaluating how consumption of renewable energy and economic complexity affect CO_2 emissions globally. It is estimated that the ECI of developed countries like Japan and Germany have high ECIs of 2.26 and 1.96 respectively, showing that these countries are highly diversified and sophisticated. Developing and low-income countries like Pakistan (-0.68), Angola (-2.5), and Cameroon (-1.61) have low economic complexity, which indicates that these countries are of low diversity and high ubiquity, and these countries export few goods. However, several studies (Neagu, 2019; Dogan et al., 2020; Boleti et al., 2021; Leitao et al., 2021; Khezri et al., 2022) evaluate the economic complexity and emission of CO_2 causality for specific regions and countries. Secondly, the study includes the partner economies. The segregation of these economies is essential because these economies are associated with a mega project named OBOR (One Belt One Road) which contributes to raising partners' economies per capita income and other economies by minimising the cost of trade. It is evaluated that the level of global income will increase by 0.7% with the help of OBOR by 2030. Additionally, this initiative will also benefit partner economies in addition to boosting China's actual revenue. Gains from this initiative are also 70%. As a result, the production of goods and services across partner economies will rise as real income rises. Such a massive production will also increase the emission of CO_2 by 54% globally. China, Russia, and India contributed 28%, 5%, and 6% of global CO_2 emissions respectively in 2020 (International Energy Agency (IEA), 2020). Thirdly, the study incorporates recent panel data methods, such as a second-generation econometric model, which may reflect the slope homogeneity and cross-sectional dependence experienced among several economies around the globe. In order to validate the non-stationary variables appropriately, the study incorporates multiple cross-sectional dependence (CD) tests that assume cross-sectional homogeneity (Pesaran, 2007). Following this, Westerlund co-integration is utilised as it considers the CD issue (Pesaran, 2015). Similarly, the estimators assume the variable stationarity which may lead to biased quantification if the sample trails non-stationarity. However, this study used the panel data model with multi-factor residual configuration which is reflected as a mutually correlated impact subject to both cross-sectional dependence (CD) and heterogeneity (Pesaran, 2007, 2015). The proposed estimators derive efficient and consistent estimates (Westerlund and Edgerton, 2008). Moreover, the study helps policymakers to articulate notable effects to implicate operative strategies to mitigate environmental deterioration.

The research questions corresponding to the objectives are:

1. What is the role of economic complexity on environmental quality in OBOR countries?
2. What is the role of renewable energy on environmental quality in OBOR countries?
3. What is the role of economic activity on environmental quality in OBOR countries?
4. What is the role of industrialisation on environmental quality in OBOR countries?
5. What is the role of trade openness on environmental quality in OBOR countries?

The remaining study is structured as follows. Section 2 depicts the literature review, Section 3 represents data and methodology, Section 4 emphasises estimated findings, and the final section covers the study's conclusion.

2. Literature Review

2.1 Relationship between economic complexity and CO_2 emission

Understanding environmental deterioration and its causes has become increasingly important due to global warming, climate change, and public awareness of these problems. Leading researchers in the field of environmental studies have stressed the significance of simple economic progress as a primary cause of environmental degradation (Kijima et al., 2010; Jayanthakumaran et al., 2012). Economic complexity measures the amount of information ingrained in an economy's productive structure of the knowledge intensive industry. The study on environmental quality concerning economic complexity was conducted by Can and Gozgor (2017). By utilising the French data set, they exposed that sustained energy use has an advantageous and persistent effect on carbon emissions. Furthermore, they also discovered that increased economic complexity lowers long-term carbon emissions. Dogan et al. (2019) also examined carbon emissions and economic complexity links emphasising how economic complexity can prevent environmental harm. According to Alvarez-Herranz et al. (2017), when economic complexity rises in developing nations, emissions rise due to scale-effect harm that is more severe. Neagu and Teodoru (2019) found the opposite, concluding that a rise in economic complexity suggests excessive environmental deterioration.

The configuration of country's production of goods is an essential indicator to determine the environmental quality. An increase in economic complexity shifts the production towards more sophisticated products from a low productive agriculture economy. This shift in production may cause an increased consumption of energy that further contributes to elevating the emissions of CO_2. On the contrary, economic complexity enhances the structural transformation, reflecting more capabilities and advance knowledge implanted in an economy. Therefore, more complex economies have a better technological solution which may further enhance the quality of environment (Kaufmann et al., 1998; Mealy and Teytelboym, 2020). However, green inventions substitute non-sustainable and primary-energy intensive skills and production, leading to a cleaner and more resource efficient economy (Hidalgo and Hausmann, 2009). Gala et al. (2018) confirm that an increase in economic complexity will lead to an increase in technological innovation, while Gramkow and Anger-Kraavi (2018) elucidate that indicators of non-green innovation are similar to green innovations. That is why it may be possible that ECI promotes green innovations that further raise environmental performance.

Furthermore, Can and Gozgor (2017) evaluated the EKC (environmental Kuznets curve) phenomena using the ECI for the French economy between 1964-2014. The empirical findings reveal that higher economic complexity overwhelms the emission of CO_2 in the long run. Neagu and Teodoru (2019) investigate the economic complexity and environmental degradation association using a 25 European economies panel from 1995-2016. The empirical results confirm the positive economic complexity and greenhouse gas emissions association. However, Dogan et al. (2019) estimate that economic complexity may affect the emission of CO_2 in several ways at different phases of income and development. An upsurge in economic complexity may increase the emission of CO_2 among higher-, middle-, and lower-income economies while reducing emissions among high-income economies. They incorporated the panel of 55 economies from 1971-2014 and divided them into several income groups.

In addition, Yilanci and Pata (2020) examined the connections among China's economic development, economic complexity, energy use, and environmental impact from 1965 to 2016. Their findings demonstrated how China's ecological footprint has increased due to its growing economic complexity, and energy consumption. There is a possibility that economic complexity of increasing emissions, due to the scale effect leading to an increase, is harmful to the environment (Alvarez-Herranz et al., 2017). Income per capita and its squared form were consistent with the economic Kuznets curve (EKC) hypotheses in Can and Gozgor's (2017) empirical investigation which utilised a dynamic ordinary least squares (DOLS) estimator for the French experience. The authors also discovered an adverse carbon dioxide emissions and economic complexity relationship. Additionally, energy demand has a favourable effect on pollutant emissions. Ahmed et al. (2021) examined the economic complexity and CO_2 emissions relationship in developing nations . The study showed that, while high economic complexity reduces ecological footprints (EPT), low economic complexity increases environmental deterioration.

2.2 Renewable energy, economic growth, and CO_2 emission

There are ample research papers on the association among energy, CO_2 emissions, and economic progress. Throughout the past few decades, many research studies such as Dong et al. (2018), Jardon et al. (2017), and Su et al. (2020), have been done on the connection among the demand for energy, CO_2 emanations, and economic progress. Moreover, various studies found that clean energy (like wind energy, solar energy, hydro energy, and other relevant energy sources) are closely related to factors like rainfall, wind speed, humidity, and sunshine, etc. that are ultimately held responsible for a stable requirement of climate change (Harrison et al., 2002; de Lucena et al., 2010; Xingang et al., 2012; Schaeffer et al., 2012). Uzoma et al. (2012) found that the energy mix has no significant effect on sustainable development but significantly contributes to carbon emissions in Nigeria. Further, the energy mix cannot provide a continuous electricity supply and cannot utilise the available coal resources. Wang et al. (2014) empirically found that renewable energy is more vulnerable to climate change in the poorer regions of China. Esso and Keho (2016) found the interconnection among energy consumption and economic progress, and both of these variables cause CO_2 emanations in 12 sub-Sahara African regions.

Further, various studies affirmed that CO_2 emission is majorly responsible for damaging the climate (Mac Dowell et al., 2017). In addition, climate alteration is a major determinant of worldwide warming which, ultimately, causes a reduction in GDP for 139 countries (Kompas et al., 2018). Rafindadi and Usman (2019) also confirm the actuality of the EKC assumption in South Africa and empirics revealed that a 7.96% increase in energy causes a 72.52% increase in environmental degradation. Extensive literature is available that validates that energy consumption causes CO_2 emissions (Heravi et al., 2020). According to empirical findings by Wen et al. (2021), non-renewable energy utilisation causes environmental contamination and the findings affirm the validation of the EKC assumption in South Asia. Additionally, Mi and Sun (2021) avowed the reduction in climate change extenuation by using an energy mix strategy from 2013 to 2016 in the case of China.

Furthermore, a new research study by Szetela et al. (2022) found that fluctuating toward renewable energy sources caused decreased CO_2 emanations for regions rich in natural resources. Accordingly, every 1% shift towards renewable energy sources causes a 1.25% decline in CO_2 emission. Likewise, Dai et al. (2022) exposed that a renewable energy surge as a portion of the energy mix causes a minimised vulnerability to climate alteration among G7 economies. The study on the economic possessions of climate transformation emphasises how these impacts might affect various economic sectors and the necessity of mitigating and addressing these implications through adaptation and mitigation efforts. The debate on the global welfare impacts of climate change has been getting attention since the 1990s (Fankhauser, 1994, 2013; Richard, 1995). Since then, various methods have been utilised to assess and measure the economic consequences of climate variation (Hsiang, 2010; Deryugina and Hsiang, 2014; Hsiang & Jina, 2014; Burke et al., 2018; Kolstad & Moore, 2020). The influence on agriculture is one of the main economic impacts of climate alteration. Koubi (2019) affirms the adverse climate change effects on agriculture production and economic development.

Cross-confirmation of the relationship between GDP growth and climate has also been analysed using 800 plausible specifications (Newell et al., 2021). Furthermore, a similar study conducted by Custodio et al. (2022) found that every 1% rise in temperature (climate change) roots a 2% decline in the sales of suppliers.

Renewable energy is also provided by natural resources that replenish themselves more quickly than they are used up. Examples of sources that never run out include the sun and the wind. A wide range of renewable energy sources are available to us (United Nations, 2015). Sharif et al.'s (2019) study compare carbon emissions and energy use (non-renewable and renewable). They discovered that clean energy reduces CO_2 emissions, whereas non-renewable energy increases them. They also discovered that CO_2 emissions decreased as the economy grew. While visiting G7 countries, Destek (2016) investigated the renewable energy and carbon emissions connection. Similarly, Aslan (2013) noted a decrease in emissions brought on by using renewable energy. The neighbourhood benefits by reducing consumption and land-based CO_2 emissions (Djellouli et al., 2022; Murshed et al., 2022; Yang et al., 2022).

Trade that involves the movement of goods has been linked to transnational pollution and the relocation of the manufacturing industries. However, economically it is advantageous for nations to look for trade advantage and trade may have also been accompanied by more significant pollution or the destruction of natural resources (Harris, 2004). Contrarily, commerce frequently catalyses environmental progress by promoting the export of ecologically beneficial goods (OECD, 2017). For instance, wealthier nations can export their emissions by moving industrial operations to less developed parts of the world where the service sector has risen in relative prominence (Arrow et al., 1995; Stern et al., 1996). Due to the advancement of transportation technologies, global trade is growing faster than the economy. Since it separates consumption from production, the expansion of international trade raises the possibility that environmental damage may go unnoticed. (Steen-Olsen et al., 2012; Lenzen et al., 2012b). In addition, more open trade is associated with more pollution (Managi et al., 2009).

Numerous researchers worldwide have investigated the relationship between environmental variables in light of the significance of environmental excellence for a nation's long-term development. The issue is discussed in recent studies that have been conducted. Ahmed et al. (2021) looked at how Japan's CO_2 emissions will change due to investments in clean energy development and economic growth. The findings indicated that Japan's CO_2 emissions increased due to economic expansion. Kanat et al. (2022) also explored the same outcomes in Russia. He et al. (2021) examined how the top 10 countries undergoing energy transformation are affected by the European Union, economic progress, clean energy, and globalisation. The results supported the long-term trend of rising carbon emissions caused by economic expansion and the co-integration of variables. Hanif et al. (2019) examined the economic progress and fossil fuel usage relationship for several Asian nations using data from 1990 to 2013. They did this by utilising the ARDL model. The research confirmed that fossil fuel demand and economic expansion cause air pollution. Moreover, they offered proof of a one-way demand for energy resources and economic progress causal relationship that further supported the growth theory. Consequently, it is quite clear how recent studies contribute to the existing literature because the major partner economies of OBOR are experiencing growth in the domain of agriculture and industry. However, these economies are still vulnerable to environmental deterioration and this is something that needs to be explored. Further, the tropical countries are facing the major brunt of climate change. The majority of high-income economies are switching to sustainable energy such as wind, biomass, and solar energy. However, these economies have high economic complexity, thus reflecting production diversification.

3. Model and Description of Data

This study includes a panel data structure of 16 high-income, 22 upper-middle income, 18 lower-middle income, and 20 low-income country groups to estimate economic complexity, renewable energy demand, per capita income, industrialisation, trade, and emission of CO_2 relationships from 1998-2021. Bearing in mind the definition of the World Bank[2], the division of economies are based on income level . Data on all variables, except economic complexity, has been taken out of World Development Indicators (WDI), while economic complexity has been taken from the Atlas database. There are 18 partner economies of OBOR included in the study because many structural changes have occurred among these economies due to the swift rise in CO_2 over the last several years. Some partner economies such as India, Brazil, Russia, and China contributed 3%, 0.94%, 3.80%, and 11% in global emission of CO_2, respectively during 1990. However, the emanation among these economies increased and reached 5%, 1.15%, 6%, and 16% among India, Brazil, Russia, and China, respectively in 2007. Japan, USA, India, and China are considered the most significant global emitters of CO_2. However, every year, the two fastest-rising economies, India and China, contribute 8% and 11% respectively to the emission of CO_2. It is the need of the hour to curtail the emission of CO_2 among partner nations to harmonise the world's environmental quality (The World Bank, 2007; Murray et al., 2009; Tamazian et al., 2009).

Pursuing the research of Neagu (2019), Dogan et al. (2020), and Khezri et al. (2022), the economic complexity, renewable energy demand, and other control effects on the emanation of CO_2 has been comprehensively discussed by using the following model in Equation 1.

$$co_2 = f(ec, ren, gdp, iva, tra) \tag{1}$$

[2] Accessed from https://datatopics.worldbank.org/world-development-indicators/stories/the-classification-of-countries-by-income.html

Due to linear specification, all variables are converted into natural logarithmic form as this specification ensures more consistent, comparable, and reliable estimates (Sarwar et al., 2017; Shahbaz et al., 2017; Neagu, 2019). Furthermore, the coefficient value is changed into elasticities of homogenous units, making this analysis more comparable. The transformed equation looks like this:

$$lco_2 = \beta_0 + \beta_1 lec + \beta_2 lren + \beta_3 \lg dp + \beta_4 liva + \beta_5 ltra + e_t \quad (2)$$

In addition, lCO_2 signifies the natural logarithms of CO_2 emanation in metric tons per capita. Simultaneously, all explanatory variables are represented as lec, lren, lgdp, liva, and ltra, which show the economic complexity index, per capita consumption of renewable energy, real per capita income, per capita value addition of the industrial sector, and trade (% of GDP). Employment of valuable knowledge in an economy's manufacturing process is represented as economic complexity. The complex economies yield diverse commodities with the help of knowledge-based innovative technologies and alternative sources of energy such as renewable. However, simple economies rely on technologies based on simple fossil fuel and non-renewable energy resources for the production of commodities (Neagu and Teodoru, 2019; Dogan et al., 2020). Below, Table 1 shows the detailed variable descriptions. The emanation of CO_2 has been used as a proxy for the quality of the environment because carbon emanation, which originated from fossil fuels and other related sources, is considered the main danger to the environment in the prevailing energy system of the world. However, an emanation of carbon accounts for the foremost segment among greenhouse gasses essential in creating global warming (Denman et al., 2007).

Table 1 - INSERT HERE

Many studies, including Neagu (2019), Dogan et al. (2020) and Khezri et al. (2022), analysed environmental degradation, renewable energy use, and economic complexity connection. However, Neagu and Teodoru (2019) reveal the negative economic complexity and emanation of CO_2 relationship due to variations in energy efficiency and composition, while economic complexity also deteriorates the environmental quality due to a rise in the production level to meet the existing energy demand. Moreover, Neagu (2019) elucidates that economic complexity contributes to the level of pollution during the preliminary phases of exports due to the usage of potential resources in order to uphold the exports of that product while, after a specific phase, economic complexity mitigates the quality of the environment by utilising green technologies and resources. In addition, the industry requires more energy to meet the existing public demand. In this situation, the role of renewable energy is essential to minimise fossil fuel reliance. Renewable energy is considered the backbone for carbon-free economic accomplishments because it accounts for 19.3% of global energy use (Dogan and Seker, 2016). Furthermore, the Hecksher-Ohlin trade model analyses that developed economies pay more attention to the production of capital-intensive products. In contrast, developing economies focus more on labour and natural resources-intensive commodities. The movement and production of these commodities among several economies will deteriorate the environment. However, liberalised economies are less polluted than less liberalised ones because trade liberalisation would accelerate the adoption of environmentally friendly and sustainable technologies due to pressure from competition across various economies. (Grossman and Krueger, 1991; Kivyiro and Aminen, 2014).

4. Empirical Strategies and Discussion

Initial cross-sectional dependence (CD) and unit root tests were conducted to verify whether the series was independent and stationary. The panel co-integration test was conducted in the second stage to ensure variables were related in long run. The third stage involved numerically estimating long-run elasticities at aggregate level. Identifying the causal direction was the fourth step.

4.1 Cross sectional dependence tests

Confirming CD is essential when N and T are high in the econometric study (Usman et al., 2019; Apergis et al., 2020). It examines the data dependence across the cross sections developed by Friedman (1937), Pesaran (2004), and Breusch and Pagan (1980), as well as the Lagrange Multiplier (LM) test. Pesaran's (2004) CD test performed better than the LM test when N > T. Pesaran's (2004) CD test is as follows. Here, θ represents the pairwise correlation coefficient, whereas t and n stand for time and nation, respectively.

$$CD = \frac{\sqrt{2t}}{[n(n-1)]} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \theta_{ij} \qquad (3)$$

Table 2 - INSERT HERE

Table 3 - INSERT HERE

The estimated outcomes of the CD of discussed samples using Pesaran's (2007) tests are reported in Table 2. However, Pesaran's (2004) and Friedman and Brush-Pagan's (1980) LM tests are reported in Table 3. The empirical findings of Pesaran (2007) prove that all variables are cross-sectionally dependent on a particular sample and that the H_o of cross-sectional independence is rejected in high-, upper-middle-, lower-middle-, low-income, and BRI economies. Moreover, the values of Pesaran's

(2004) and Friedman and Brush-Pagan's (1980) LM tests are statistically significant, thus confirming the rejection of the cross-sectional independence H_o and the fact that variables are cross-sectionally dependent among the samples under discussion.

4.2 *Panel unit root tests*

CD supports using Pesaran's (2007) second-generation unit root test in this situation. Incorporating τ statistics into the cross-sectional (CADF) regression's OLS (ordinary least square) estimator **(λ_i),** Pesaran's (2007) test of unit root constructs test statistics and uses the cross-section mean as a proxy for the common component.

$$\Delta_{y_{it}} = \theta_i + \lambda_i \, y_{i,t-1} + \rho_i \Delta_{yi} + \partial_{ij} \quad (4)$$

The augmented IPS test is also considered using the following mathematical formulas.

$$\text{CIPS (L, t)} = \overline{\overline{K}} = L^{-1} \delta_{i=1}^{N} \, K_i \text{ (L, t)} \quad (5)$$

Additionally, $\partial_{ij}(L, t)$ represents the statistics of the Augmented Dickey-Fuller for the i^{th} unit of the country and is determined by the coefficient $(y_{i,}K - 1)$ of the t statistics in the CADF regression.

Table 4 - INSERT HERE

If the discussed sample is large enough, such as t >20, the implication of human behaviour and its inaccuracy becomes significant. In these circumstances, the assumptions of OLS for given indicators have been violated such that mean and variances are independent of time (Canning and Pedroni, 2008; Gujarati, 2009; Eberhardt and Teal, 2011). A panel unit root test has been used in order to analyse the problem of stationarity in given series of data. Table 4 represents the estimated outcomes of the CIPS unit root test introduced by Pesaran (2007). H_o confirms that mean and variances are time variants while vice versa signified the alternative hypothesis. Table 4 proves that the H_o has been rejected and, in the event of a trend, establishes that none of the variables exhibits the characteristics of a unit root problem from the outset. However, in the event of a trendless initial difference among the high-, upper-middle-, lower-middle-, low-income, and BRI nations, mean and variance are constant throughout time.

4.3 Panel Co-integration tests

Once the variables are arranged in order I(1), the panel co-integration techniques suggested by Pedroni (1995) and Westerlund (2007) are employed to investigate whether there is co-integration between the variables. Pedroni's (1995) co-integration test uses specific settings to show the heterogeneity issue across every panel. By taking into account the interdependence of various features among various nations, the equation for panel co-integration can be expressed as follows:

$$\partial\sigma_{it} = \beta_i + \eta_{it} + \partial\sigma_{i,t-l} + \varepsilon \tag{6}$$

Next, the panel co-integration method proposed by Westerlund (2007) was used and this has been found to have two fundamental benefits. Initially, common factor limitations are invalid under this technique since it analyses structural dynamics rather than residual dynamics in estimation. Secondly, it can handle trend terms, serially linked residuals, and effects particular to a given country. The co-integration proposed by Westerlund (2007) is based on four different statistics: the first two are known as panel tests and denoted by P_t and P_a whereas the following two are group-mean tests designated by G_a and G_t. The panel test's H_a is that the panel as a whole is co-integrated ($H_{1l} \coloneqq \beta_i = \beta <$

$0 \; for \; all \; i$). This is in contrast to H_a, which claimed that at least one component in the panel is co-integrated and was tested using group-mean tests ($H_{1g} := \beta_i < 0 \; for \; at \; least \; one \; i$).

Table 5 – INSERT HERE

Table 5 presents the estimated findings of the multivariate of Pedroni (1995) and Westerlund's (2017) co-integration methods. The outcomes of Table 5 confirm that the H_o of no co-integration among given variables has been rejected. This evidence shows long-run economic complexity, renewable energy, economic progress, trade, and CO_2 emission relationship among discussed samples.

4.4 Long-run estimates

Dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) are applied to calculate the consistent numerical values of long-run elasticities. Kao and Chiang (2000) expressed that DOLS generate reliable estimates in co-integrated panels and perform well in small sample settings. However, DOLS does not take the issue of heterogeneity into account. Pedroni (2001) proposed the FMOLS as a remedy for this problem as they provide consistent and asymptotically unbiased estimates when cross-sectional variation is present. The following is how the coefficient ϕ^*FMOLS is calculated:

$$\phi^* = L^{-1} \sum_1^N \times \left(\left(\sum_1^K \left(O_{it} - \underline{O_i} \right) \right)^2 \right)^{-1} \left(\sum_1^K \left(O_{it} - \underline{O_i} \right) Y_{it}^* - K u_i \right) \quad (7)$$

Where,

$Y_{it}^* = \left(Y_{it} - \underline{Y_i} \right) - \frac{v_{21i}}{v_{22i}} \partial O_{it}$

$$u_i = \theta_{21i} + \nu_{22i}{}^{o} - \frac{\nu_{21i}}{\nu_{22i}} \left(\theta_{22i} - \nu_{22i}^{o}\right)$$

Table 6 – INSERT HERE

Using panel FMOLS and DOLS, the estimations for *t* economic complexity, renewable energy use, and CO_2 emission links have been provided in Table 6. The estimation findings demonstrate that economic complexity enhances environmental quality by lowering CO_2 emissions in high- and low-income economies. In contrast, upper-middle and lower-middle-income economies indicate a significant and favourable link with CO_2 emission. Additionally, a positive correlation is found between BRI economies. However, using both FMOLS and DOLS, renewable energy decreases the quantity of CO_2 in the atmosphere across all economies. Additionally, Table 6 demonstrates that commerce, with the exception of high- and low-income nations, has a negative link with CO_2 emission. At the same time, industrial value addition exhibits a positive and substantial association with CO_2 emission across all sample economies. These results align with those of Kijima et al. (2010), Djellouli et al. (2022), and Murshed et al. (2022).

The pooled mean group (PMG) method suggested by Pesaran et al. (2004) was applied to confirm the results' dependability. One benefit of using the PMG approach is the ability to estimate the adjustment dynamics between the short- and long-run. The example that follows demonstrates using PMG to calculate long-run coefficients when co-integrated variables are given:

$$\sigma_{it} = \eta_i + \sum_{g=1}^{S} \theta_{ij}\sigma_{i,t-l} + \sum_{g=0}^{T} \vartheta_{il}Y_{i,t-l} + \epsilon_{it} \qquad (8)$$

The error correction model (ECM) is used to estimate the short runs which is comparable to the long-run coefficients.

$$\sigma_{it} = \beta_i + \sum_{g=1}^{S} u_{il}\, \partial\sigma_{i,t-l} + \sum_{g=0}^{T} \mu_{il}\partial Y_{i,t-l} + \eta_{il} ect_{t-i} + \varepsilon_{it} \quad (9)$$

The residual from the previous equation, assumed to be identically and independently distributed with zero mean and fixed variance, is represented by the error correction term (ECT) and denoted as (ect_{t-i}) and ϵ_{it}. However, following a significant shock, (η_{il}) shows the rate of adjustment in the long-term direction. The coefficient sign should be significant and negative after estimation. Finally, the Hausman test examines the H_o of long-run coefficients homogeneity.

Table 7 - INSERT HERE

Table 8 - INSERT HERE

Tables 7 and 8 discuss the empirical results of the mean group (MG), pooled mean group (PMG), and dynamic fixed effect (DFE). The empirical findings of MG, PMG, and DFE demonstrate that, except for high-income countries, all mentioned economies will decline in environmental quality as economic complexity rises. However, across all of the chosen sample economies, the demand for renewable energy shows a negative and considerable correlation with carbon emissions. According to these estimates, from 1998 to 2021 renewable energy sources will enhance global environmental circumstances. Regarding economic complexity and renewable energy use across all sectors of economies, the empirical findings of PMG, MG, and DFE are comparable. These results are consistent with those of Abbasi and Riaz (2016), Murshed et al. (2022), and Yang et al. (2022). Table 7 also includes the estimated value of the Hausman test which is insignificant among all economies except for those with low incomes. This supports the null hypothesis that efficient estimates of PMG are valid across all economies except those with low incomes. This leads to the conclusion that, except for low-income economies, PMG provides more accurate and efficient estimates.

4.5 Granger causality

Typically, to confirm the link between variables, the causality test devised by Engle and Granger (1987) is used. The generalised method of moments (GMM) and three-stage least squares (3SLS) are less successful than PMG estimates since they do not use mean and pooling. Additionally, the estimator of PMG also safeguards the significant variations in the characteristics of the various nations. As a result, PMG estimates are more accurate than DOLS and FMOLS estimates. However, once all variables become stationary, the PMG technique can be used to assess the causality. The Vector Error Correction Model can be used as indicated in the equations given below to assess the short-run connection between the provided variables.

$$\sigma_{it} = \chi_0 + \sum_{g=0}^{T} \eta_{ig} \partial Y_{i,t-i} + \eta_1 ect_{t-1} + \epsilon_{1t} \tag{10}$$

$$\partial Y_{it} = \chi_o + \sum_{g=0}^{T} \delta_{ig} \partial Y_{l,t-l} + \sum_{i=1}^{T} \psi_{ig} \partial \sigma_{l,t-i} + \eta_2 ect_{t-1} + \epsilon_{2t} \tag{11}$$

ϵ_{1t}, the residual is given in the above equation. It has a consistent variance and an identical, dispersed average value of zero. The ECM was used to derive the value of (ect_{t-1}), which shows how long-run equilibrium is associated with this number, however, the coefficient (η) shows convergence toward long-term study. MG and PMG will use the estimation from the ECM. Furthermore, whereas MG allows for individual variation in short- and long-run circumstances, PMG only considers cross-country heterogeneity in the short term. The H_o demonstrates that Granger causality does not apply in the short-run (H_0: $\psi_i = 0$). However, an alternative theory permits Granger causality to exist in the event of a short-run ($H_1: \psi_i \neq 0$) by taking into consideration each (g) value and (i). Using different lagged explanatory factors, the short-run causality has been extracted.

Table 9 - INSERT HERE

Finally, using Granger causality, the study empirically investigates the short-run association between the given indicators. Table 9 reports that economic complexity exhibits bidirectional causality among all selected economies except low-middle-income nations. However, renewable energy demand confirms the bidirectional causality among all selected economies. These conclusions are consistent with those of Murshed et al. (2022) and Yang et al. (2022). The significant and negative values of ect_{t-1}.demonstrate that all of the offered economies are moving in the direction of long-term equilibrium.

4.6 Discussion

The empirical findings confirm the positive and significant economic complexity and carbon emission association among upper-middle-, lower-middle-, low-income economies, and overall sample. However, along with increasing economic complexity environmental standards improve among high-income economies. The empirical verdict is consistent with Minondo and Requena-Silvente (2013), Hausmann et al. (2014), Can and Gozgor (2017), and Dogan et al.'s (2020) findings. Development theories elucidate that technological advancement, structural change, and product diversification is crucial for the growth of an economy. Therefore, economic development is backed by the ability to produce and export Similarly, economic complexity helps generate effective products, e.g., renewable energy sources within the economy. Knowledge-intensive commodities can be produced with the help of extensive scale knowledge management and production networks. The greater economic complexity of any country indicates its ability to produce more value-added and complex commodities. That is why developed economies may have a comparative advantage in producing commodities while being required to increase harmonisation among highly skilled labour (Hidalgo and Hausmann, 2009; Hidalgo et al., 2007; Minondo and Requena-Silvente, 2013; Neagu and Teodoru, 2019). The outcome is also explainable by the environmental Kuznets curve, whereby a high increase in economic complexity tends to show an improvement in the environment.

The ecological deficit defines the difference between bio-capacity and ecological footprints. Economic complexity may deteriorate the environmental quality, but economic complexity also offers sufficient resources such as knowledge, competitiveness, and institutions to explain the deficit in the ecological environment. The rise in economic complexity represents a country's highly skilled human capital and abilities. These skills may enhance research and development activities, further improving the environmental quality among developed economies. Moreover, economic complexity may also increase the per capita income, which represents the availability of funds for such activities of Research and Development (R&D), especially in the field of alternative energy sources and accessibility of clean and energy-efficient technologies, which further stimulates a carbon-free economy. The institutional quality and governance in the competitive environment may elevate other indicators such as networks of knowledge and efficient utilisation of resources which further raise the quality of the environment (Hausmann et al., 2014; Can and Gozgor, 2017). Contrary to the above discussion, a rise in the level of complexity among exported commodities may deteriorate the quality of air, which means an increase in exposure to $PM_{2.5}$ upsurge in CO_2, nitrous oxide, and methane emanation which, in turn, minimises the demand for renewable energy sources and increase the traditional energy use, especially among developing economies. Similarly, an upsurge in economic complexity shifts the structure of an economy from a less productive agriculture sector to high productive sector to meet the population's existing demand. This phenomenon requires greater energy use which consequently raises the emanation of CO_2 in the atmosphere (Kaufmann et al., 1998; Nejat et al., 2015).

In addition, various investment companies reveal that western, southeast, and central Asia are essential in driving growth in global output in the impending decades. Predictions state that BRI economies will contribute 50% of global GDP by 2030. The enormous increase in economic progress will depreciate the environment around the world. Moreover, empirical evidence confirms that increased trade among several economies results in more CO_2 emissions (Kivyiro and Aminen, 2014; Holly, 2015; Jebli et al., 2016). With the aid of trade liberalisation, numerous polluting companies relocated from industrialised nations with rigorous environmental regulations to developing nations with weak environmental legislation. This process will uplift the level of atmospheric CO_2, particularly among developing economies. However, it is also proved that BRI economies contain many industries based on coal and fossil fuels to manufacture household goods. These industries support the pollution haven hypothesis. Additionally, it is predicted that a rise in per capita income may deteriorate climate stability, further affecting labour productivity. That is why environmental deterioration consists of biodiversity and human well-being loss and depletion of natural resources (Azhar et al., 2007; Alam et al., 2011).

Tropical countries are most susceptible to environmental degradation because of their high population, agricultural orienteers, and poor governance (Schlosberg, 2013). For the context of tropical countries, this study has included the data of 28 tropical countries comprising of 14 Asian and 14 African countries. There was one high-income, four high-middle-income, 15 lower-middle-income and eight low-income nations. The results of FMOLS and DOLS estimates confirm that a rise in economic complexity increases carbon emissions for upper-middle- and lower-middle-income nations, while the outcomes of PMG, MG and DFE demonstrate a rise in economic complexity increases carbon dioxide in all income groups. This highlights the need to regulate and manage the nature of economic complexity, which may be environmentally friendly. Nations in pursuit of economic complexity must also adhere to the sustainability aspect.

5. Conclusion

This study empirically analysed economic complexity, renewable energy demand, and CO_2 emission association among high-, upper-middle-, lower-middle-, and low-income nations from 1998-2021. The OBOR (One Belt, One Road) project's partner nations are also included in the study. The main goal of this project was to strengthen the connections and support across various nations to increase trade volume at the lowest possible cost. These economies account for 65% of the global population so their presence is crucial. The majority of the partner economies are growing and demonstrating their primary concerns with enhancing economic activity at the expense of the environment. This study used a CD test that identified the existence of homogeneity among various global economies. Cross-sectional dependency also affected the study's analysis and forced the use of a second-generation unit root test to confirm that all variables were able to resolve the unit at first difference problem. The panel co-integration and ARDL model are also considered to determine the likelihood of a long-term relationship between the given variable and the given factor. The study used several econometric models to empirically calculate the given variables' long run coefficients, including FMOLS, DOLS, MG, PMG, and DFE. However, the effectiveness and robustness of estimates were ensured using various econometric techniques. The direction of short run causation among the variables under consideration was established using Granger causality.

The estimation findings indicated that, except for high-income nations, economic complexity weakens the primacy of the environment across the whole sample of countries. It was observed that greater economic complexity will result in better environmental integrity among high-income economies. The prime intention of this association is that during the initial stages of development the primary concern of economies is to specialise in less complex products by using heavily polluted industries. However, high-income economies are moving from high-intensive carbon commodities to less carbon-intensive commodities and their exports. Keeping this in mind, these standpoint policymakers should implement policies that help reduce carbon emissions among low- and low-middle-income economies. Similarly, the estimated findings also revealed that utilisation of renewable energy sources improved the environment by reducing the emission of CO_2 among all selected samples of economies because innovative renewable energy sources substituted the fossil fuel-based demand for energy. Therefore, using renewable energy sources mitigates the environment degradation among all nations around the globe.

The estimated outcomes have several noteworthy implications for the improvement of the environment globally. The empirical findings suggest that countries should modify the production of commodities to enhance the environment's integrity. Moreover, changes in structural dynamics from primary to technological advancement may deteriorate the environment. To transform the quality of the environment, the government should allocate responsibilities to lower establishments. Carbon emitting programs have been encouraged in decentralising states to enhance the environment and develop freeloader programs that sell polluting industries in several nearby regions. However, smaller state bodies are motivated to trail severely polluted businesses and enhance the environment's efficiency. In addition, the government should introduce several programs that motivate state entities to utilise renewable energy sources. This phenomenon will control environmental damage, enhance output, and ensure environmental sustainability. Moreover, the importance of renewable energy demands among several economies indicates that countries are moving in the right direction toward sustainable growth and the environment. However, policymakers should take some pre-emptive footsteps to expand energy sources, minimise the dependency on fossil fuels, and enhance the utilisation of greener energy as that increase in industrialisation must be accompanied with a faster transition to cleaner energy.

These two pre-requisites, along with sustained growth and an outward looking approach (globalisation), are advised by this study's complexity management policy options.

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Table 1: Description of Variables

Variables	Construction	Sources	Variables used in literature
Emission of Carbon Dioxide	Metric tons per capita	World Development Indicator (WDI)	(Waheed et al., 2018; Mensbrugghe, 2019; Leitão et al., 2021)
Index of Economic Complexity	Index (0 to 1)	Atlas database	(Neagu and Teodoru, 2019; Dogan et al., 2020; Leitão et al., 2021)
Economic Growth	Real per capita income	WDI	(Abbasi et al., 2021; Caglaor et al., 2022; Zehang et al., 2021)
Renewable Energy Demand	Energy Consumption % of total energy consumption	WDI	(Apergis et al., 2010; Dogan and Seker, 2016; Ocal and Aslan, 2013)
Trade	Trade (% of GDP)	WDI	(Kivyiro and Aminen, 2014; Lenzen et al. 2012b)
Industrial Value added	Value addition of industrial sector % of GDP	WDI	(Djellouli et al., 2022; Murshed et al., 2022; Yang et al., 2022)

Table 2: Cross-Sectional Dependence Pesaran (2007)

Variables	lco_2	lec	$lren$	$lgdp$	$liva$	$ltra$
High-Income Economies						
CDF	2.23***	5.85***	12.17***	16.67***	12.65***	13.62***
Upper-Middle-Income Economies						
CDF	27.12***	4.02***	0.77**	42.67***	8.43***	10.34
Lower-Middle-Income Economies						
CDF	53.30***	11.66***	35.68***	47.79****	32.07****	8.65***
Low-income Economies						
CDF	12.31***	2.51***	3.70***	8.61***	9.03***	5.79***
BRI economies						
Statistics	3.09***	9.71***	0.74*	45.62***	30.44***	7.41***

*, ** and *** symbolises the significance level at 10%, 5%, and 1%

Table 3: Cross-Sectional Dependence Comparison

Tests	Pesaran CD (2004)	Breush-Pagan (LM)	Friedman CD
High-Income Economies			
Coefficient Value	6.24**	4.38	18.24*
Upper-Middle-Income Economies			
Coefficient Value	2.80**	5.83	38.14**
Lower-Middle-Income Economies			

Coefficient Value	11.85***	9.85*	37.06***
Low-Income Economies			
Coefficient Value	4.75***	6.53**	39.22***
BRI economies			
Coefficient Value	9.88***	5.28**	22.19***

*, ** and *** symbolises the significance level at 10%, 5%, and 1%

Table 4: Unit root test

Pesaran (2007)				*High-income Economies*			
Variables		lco_2	lec	$lren$	$lgdp$	$liva$	$ltra$
Without Trend	Level	2.90	0.18	1.43	1.84	0.19	2.78
	1st Difference	4.26***	2.52***	1.38**	1.98***	2.36***	5.86*
With Trend	Level	1.71	0.25	0.87	0.10	2.70	0.50
	1st Difference	3.86***	2.07***	2.96***	2.87***	3.45**	2.36***
Maddala and Wu (1999).							
Without Trend	Level	21.38	35.62*	24.12	28.52	43.52	43.96
	1st Difference	35.68***	58.71***	35.28***	31.28***	60.36***	38.13***

With Trend	Level	24.98	68.42*	14.25	29.02	25.65	50.52*
	1st Difference	28.25***	71.25***	20.86***	29.32*	28.37**	54.62***
Pesaran (2007)				*Upper-Middle-Income Economies*			
Without Trend	Level	1.19	4.83*	2.51	1.08	0.23	2.99
	1st Difference	2.48*	2.66***	3.78***	1.55**	6.83***	3.12*
With Trend	Level	0.28	1.84	2.19	2.22	2.12	0.558
	1st Difference	1.28***	2.32***	3.26***	2.68***	2.56***	1.682*
Maddala and Wu (1999).							
Without Trend	Level	64.17*	68.25*	48.97	40.95	35.95	39.43
	1st Difference	59.75***	84.06***	53.55***	52.16**	40.28*	44.05*
With Trend	Level	32.42	82.45*	41.18	33.95	20.40	45.60
	1st Difference	33.75***	54.77***	66.92***	28.31***	25.42***	54.04**
Pesaran (2007)				*Lower-Middle-Income Economies*			
Without Trend	Level	0.86	1.51	2.97	2.26	1.13	0.74
	1^{st} Difference	5.26****	3.23***	5.28***	5.32****	3.26***	2.12***
With Trend	Level	3.63	0.87	4.43	5.03*	0.50	2.63
	1^{st} Difference	3.89***	2.95***	5.62***	6.38***	2.62***	3.85***

Maddala and Wu (1999).							
Without Trend	Level	15.92	96.35	18.94	10.45	21.56	33.84
	1st Difference	18.63***	98.65**	23.33***	13.56***	27.47**	35.82***
With Trend	Level	26.03	64.65	10.06	83.28	93.83	83.31
	1st Difference	28.23***	67.25***	13.27***	90.25***	95.23***	85.21***
Pesaran (2007)				*Low-income Economies*			
Without Trend	Level	1.32*	0.90	3.56	0.39	0.19	0.98
	1st Difference	2.13***	2.13***	4.58***	2.25***	2.56***	2.56***
With Trend	Level	0.11	3.23	1.25	1.41	0.62	2.75*
	1st Difference	2.56***	4.35***	2.26***	2.42***	2.26***	3.25***
Maddala and Wu (1999).							
Without Trend	Level	13.27	18.01	11.71	7.31	15.25	20.46*
	1st Difference	14.28***	20.24***	21.21***	10.64***	16.25***	25.25***
With Trend	Level	14.19	11.77	7.75	21.77	10.99	15.72
	1st Difference	16.25***	12.62***	22.24***	25.34***	16.36***	19.02***
Pesaran (2007)				*BRI economies*			
	Level	1.03	0.90	0.46	1.66	2.08	2.32

Without Trend	1st Difference	2.51***	3.21***	2.15***	3.12***	3.42***	4.35***
Without Trend	Level	0.13	2.77	1.86	2.33	3.45*	1.63
	1st Difference	2.35***	3.62***	2.36***	3.68**	5.62***	2.35***
Maddala and Wu (1999).							
Without Trend	Level	18.78	95.22	33.93	34.62	37.58	40.53
	1st Difference	23.35***	99.35**	36.98***	35.26*	42.99***	60.35***
Without Trend	Level	19.35	21.23	46.74*	10.47	14.71	60.20*
	1st Difference	20.35***	33.26***	48.68***	19.36**	25.62***	70.23***

*, ** and *** symbolises the level of significance level at 10%, 5%, and 1%

Table 5: Pedroni and Westerlund co-integration test

Statistics	G_τ	G_α	P_α	P_τ
High-Income Economies				
Prob.	0.51	0.68	0.68	0.87
Robust Prob.	0.07**	0.00***	0.05**	0.04*
Upper-Middle-Income Economies				
Prob.	0.25	0.85	0.51	0.98
Robust Prob.	0.01***	0.02***	0.01***	0.04***
Lower-Middle-Income Economies				
Prob.	0.71	0.62	0.61	0.97
Robust Prob.	0.01***	0.05**	0.04***	0.04***
Low-Income Economies				
Prob.	0.21	0.88	0.42	0.81
Robust Prob.	0.01***	0.02*	0.01***	0.01**
BRI economies				
Prob.	0.31	0.87	0.42	0.87
Robust Prob.	0.01***	0.07*	0.01***	0.06**

Pedroni Co-integration						
Within-Dimension Statistics				Between-Dimension Statistics		
v statistic	Rho	P_p	ADF	Rho	P_p	ADF
High-Income Economies						
-5.73***	-2.78**	-28.3***	-13.9**	2.76***	2.82**	4.25***
Upper-Middle-Income Economies						

-8.62***	-3.58**	-31.25***	-16.25**	3.62***	2.54***	5.62***
Lower-Middle-Income Economies						
-4.89***	-2.58*	-21.12***	-18.25***	2.14***	4.28**	5.35**
Low-Income Economies						
-7.14***	-3.12*	-25.12***	-18.12*	3.12***	2.12**	4.14***
BRI economies						
-5.12***	-2.12***	-32.3***	-13.14***	2.85*	2.12*	4.28**

*, ** and *** symbolises the level of significance level at 10%, 5%, and 1%

Table 6: (DOLS) Dynamic Ordinary Least Square and (FMOLS) Fully Modified Ordinary Least Square

Variables	*lec*	*lren*	*lgdp*	*liva*	*ltra*
High-Income Economies					
(FMOLS) Fully Modified Ordinary Least Square					
Coefficient Value	-0.132*	-0.884**	0.559	0.137***	-0.132***
Prob.	0.10	0.00	0.28	0.00	0.00
(DOLS) Dynamic Ordinary Least Square					
Coefficient Value	-0.102**	-0.864***	0.652	0.502*	-0.312***
Prob.	0.09	0.00	0.31	0.10	0.00
Upper-Middle-Income Economies					
(FMOLS) Fully Modified Ordinary Least Square					
Coefficient Value	0.125***	-0.632***	-0.578	0.135***	-0.460***
Prob.	0.00	0.00	0.31	0.00	0.00
(DOLS) Dynamic Ordinary Least Square					
Coefficient Value	0.242***	-0.649***	-0.742	0.405**	-0.692***
Prob.	0.00	0.00	0.54	0.09	0.00
Lower-Middle-Income Economies					
(FMOLS) Fully Modified Ordinary Least Square					

Coefficient Value	0.124***	-0.397***	-0.102***	0.780***	-0.177***
Prob.	0.00	0.00	0.00	0.00	0.00
(DOLS) Dynamic Ordinary Least Square					
Coefficient Value	0.532*	-0.707**	-0.467***	0.958	-0.264
Prob.	0.10	0.09	0.00	0.56	0.52
Low-Income Economies					
(FMOLS) Fully Modified Ordinary Least Square					
Coefficient Value	-0.438***	0.136	0.128**	0.402*	0.479
Prob.	0.00	0.58	0.09	0.10	0.62
(DOLS) Dynamic Ordinary Least Square					
Coefficient Value	-0.762***	-0.652***	0.932*	0.381	0.682
Prob.	0.00	0.00	0.10	0.53	0.68
BRI economies					
(FMOLS) Fully Modified Ordinary Least Square					
Coefficient Value	0.473***	-0.413***	-0.697***	0.345***	-0.268***
Prob.	0.00	0.00	0.00	0.00	0.00
(DOLS) Dynamic Ordinary Least Square					
Coefficient Value	0.567***	-0.256*	-0.866***	0.389***	-0.117***

Prob.	0.00	0.10	0.00	0.00	0.00

*, ** and *** symbolises the significance level at 10%, 5%, and 1%

Table 7: (PMG) Pool Mean Group and (MG) Mean Group Estimation

Variables	*lec*	*lren*	*lgdp*	*liva*	*ltra*
High-Income Economies					
(MG) Mean Group ARDL (1,0,1,1,2,0)					
Coefficient Value	-0.475***	-0.552***	0.198	-0.451	0.661***
Prob.	0.00	0.00	0.26	0.32	0.00
(PMG) Pool Mean Group ARDL (1,0,1,1,2,0)					
Coefficient Value	-0.468***	-0.186***	0.307***	-0.145***	-0.702
Prob.	0.00	0.00	0.00	0.00	0.28
Hausman Test	Statistics	6.99	Probability	0.38	PMG is appropriate
Upper-Middle-Income Economies					
(MG) Mean Group ARDL (1,1,0,2,0,2)					
Coefficient Value	0.160*	-0.525***	0.767**	0.160	-0.423
Prob.	0.10	0.00	0.09	0.53	0.67
(PMG) Pool Mean Group ARDL (1,1,0,2,0,2)					
Coefficient Value	0.326***	-0.562**	0.256***	0.789*	0.253***
Prob.	0.00	0.09	0.00	0.10	0.00
Hausman Test	Statistics	14.26	Probability	0.36	PMG is appropriate
Lower-Middle-Income Economies					
(MG) Mean Group ARDL (2,1,2,0,1,2)					
Coefficient	0.351**	-0.15***	0.484***	0.381	0.181*
Prob.	0.09	0.00	0.00	0.51	0.10

(PMG) Pool Mean Group ARDL (2,1,2,0,1,2)					
Coefficient Value	0.306***	-0.823**	0.368***	-0.648***	-0.253***
Prob.	0.00	0.00	0.00	0.00	0.00
Hausman Test	Statistics	7.80	Probability	0.68	PMG is appropriate
Low-Income Economies					
(MG) Mean Group ARDL (2,2,1,1,0,1)					
Coefficient Value	0.225*	-0.462***	0.132	0.132***	0.262***
Prob.	0.10	0.00	0.56	0.00	0.00
(PMG) Pool Mean Group ARDL (2,2,1,1,0,1)					
Coefficient Value	0.189***	-0.957***	0.471*	0.778***	-0.711
Prob.	0.00	0.00	0.10	0.00	0.65
Hausman Test	Statistics	43.26	Probability	0.00	MG is appropriate
BRI Economies					
(MG) Mean Group ARDL (2,1,0,2,0,2)					
Coefficient Value	0.382***	-0.372***	-0.182	0.325*	0.442
Prob.	0.00	0.00	0.56	0.10	0.26
(PMG) Pool Mean Group ARDL (2,1,0,2,0,2)					
Coefficient Value	0.231***	0.138***	0.752***	0.186	0.387***
Prob.	0.00	0.00	0.00	0.58	0.00
Hausman Test	Statistics	13.71	Probability	2.63	PMG is appropriate

*, ** and *** symbolises the significance level at 10%, 5%, and 1%

Table 8: DFE and PMG Estimation

Variables	*lec*	*lren*	*lgdp*	*liva*	*ltra*
High-Income Economies					
(DFE) Dynamic Fixed Effect ARDL (1,0,1,1,2,0)					
Coefficient value	-0.786***	-0.926**	0.66***	0.541	0.392
Prob.	0.00	0.09	0.00	0.38	0.51
(PMG) Pool Mean Group ARDL (1,0,1,1,2,0)					
Coefficient value	-0.468***	-0.186***	0.307***	-0.145***	-0.702
Prob.	0.00	0.00	0.00	0.00	0.28
Hausman Test	Statistics	8.23	Probability	0.78	PMG is appropriate
Upper-Middle-Income Economies					
(DFE) Dynamic fixed effect ARDL (1,1,0,2,0,2)					
Coefficient value	0.562*	-0.682***	0.256	0.582*	0.682
Prob.	0.10	0.00	0.57	0.10	0.66
(PMG) Pool Mean Group ARDL (1,1,0,2,0,2)					
Coefficient value	0.326***	-0.562**	0.256***	0.789*	0.253***
Prob.	0.00	0.09	0.00	0.10	0.00
Hausman Test	Statistics	12.50	Probability	0.25	PMG is appropriate
Lower-Middle-Income Economies					
(DFE) Dynamic fixed effect ARDL (2,1,2,0,1,2)					
Coefficient value	0.829*	-0.322***	0.601*	0.793	-0.315
Prob.	0.10	0.00	0.10	0.68	0.68

(PMG) Pool Mean Group ARDL (2,1,2,0,1,2)					
Coefficient value	0.306***	-0.823**	0.368***	-0.648***	-0.253***
Prob.	0.00	0.00	0.00	0.00	0.00
Hausman Test	Statistics	8.67	Probability	1.36	PMG is appropriate
Low-Income Economies					
(DFE) Dynamic fixed effect ARDL (2,2,1,1,0,1)					
Coefficient value	-0.921*	-0.460***	0.658	-0.249	0.693*
Prob.	0.10	0.00	0.58	0.56	0.10
(PMG) Pool Mean Group ARDL (2,2,1,1,0,1)					
Coefficient value	0.189***	-0.957***	0.471*	0.778***	-0.711
Prob.	0.00	0.00	0.10	0.00	0.65
Hausman Test	Statistics	16.23	Probability	1.86	PMG is appropriate
BRI Economies					
(DFE) Dynamic fixed effect ARDL (2,1,0,2,0,2)					
Coefficient value	0.149*	-0.505***	0.623***	-0.284	0.340***
Prob.	0.10	0.00	0.00	0.72	0.00
(PMG) Pool Mean Group ARDL (2,1,0,2,0,2)					
Coefficient value	0.231***	0.138***	0.752***	0.186	0.387***
Prob.	0.00	0.00	0.00	0.58	0.00
Hausman Test	Statistics	19.56	Probability	0.86	PMG is appropriate

*, ** and *** symbolises the significance level at 10%, 5%, and 1%

Table 9: Causality based on PMG

	Δlco_2	Δlec	$\Delta lren$	$\Delta lgdp$	$\Delta liva$	$\Delta ltra$	ec_{t-1}
High-Income Economies							
Δlco_2	1.00	0.75*	0.45*	-0.74**	0.45**	0.21	-0.36***
Δlec	-0.36**	1.00	-0.46	0.84**	0.54	-0.68***	-0.24***
$\Delta lren$	-0.42**	0.41	1.00	0.45	-0.36**	0.71*	-0.42***
$\Delta lgdp$	0.42	0.58	0.54**	1.00	0.45	0.32	-0.75***
$\Delta liva$	0.56	0.45**	0.68**	-0.41	1.00	-0.42*	-0.65***
$\Delta ltra$	0.84	0.26**	0.24	0.36	0.24*	1.00	-0.24**
Upper-Middle-Income Economies							
Δlco_2	1.00	0.84*	0.34*	-0.64**	0.24	0.36*	-0.46***
Δlec	0.76**	1.00	-0.36	0.48	0.46**	-0.72	-0.44***
$\Delta lren$	-0.36**	0.54	1.00	0.45**	-0.27*	0.71***	-0.32***
$\Delta lgdp$	0.34	0.84	0.62**	1.00	0.72	0.62	-0.65***
$\Delta liva$	0.45	0.62**	0.72**	0.54	1.00	0.36	-0.75***
$\Delta ltra$	0.84	0.31	0.28**	0.24	0.36	1.00	-0.36**
Lower-Middle-Income Economies							
Δlco_2	1.00	0.54	0.65***	0.32	0.21***	0.21***	-0.84***
Δlec	0.24***	1.00	-0.24	0.56	0.21**	-0.21***	-0.32***
$\Delta lren$	-0.67**	0.62*	1.00	0.72	-0.36***	0.32	-0.21***
$\Delta lgdp$	0.26**	0.41*	0.51	1.00	0.61	0.36	-0.56***

$\Delta liva$	0.67	0.21**	0.24	0.36	1.00	0.24**	-0.84***
$\Delta ltra$	0.32**	0.24	0.46**	0.24	0.72	1.00	-0.21**
Low-Income Economies							
Δlco_2	1.00	0.46*	0.72*	0.42	0.56	0.26	-0.51***
Δlec	0.42***	1.00	-0.62	0.56**	0.25**	-0.36	-0.72***
$\Delta lren$	-0.51**	0.75	1.00	0.28**	-0.32***	0.38	-0.35***
$\Delta lgdp$	0.36	0.32	0.62*	1.00	0.72***	0.42	-0.74***
$\Delta liva$	0.72**	0.47	0.39	0.42***	1.00	0.36**	-0.65***
$\Delta ltra$	0.46	0.32	0.47	0.35**	0.89	1.00	-0.72**
BRI Economies							
Δlco_2	1.00	0.68***	0.36**	0.72*	0.71	0.36	-0.62***
Δlec	0.87***	1.00	0.36	0.26**	0.24	-0.42**	-0.74***
$\Delta lren$	-0.63***	0.74	1.00	0.23	-0.46***	0.25	-0.21***
$\Delta lgdp$	0.47	0.26	0.36	1.00	0.64	0.78	-0.64***
$\Delta liva$	0.86**	0.56	0.24	0.42	1.00	0.27**	-0.46***
$\Delta ltra$	0.49***	0.21	0.49***	0.34	0.55	1.00	-0.29**

*, ** and *** symbolises the significance level at 10%, 5%, and 1%

Appendix

List of Countries

High-Income	Upper-Middle-Income	Lower-Middle-Income	Low-Income	Partner Economies of OBOR
Argentina	Brazil	Bolivia	Congo, Dem. Rep.	China
Venezuela, RB	Botswana	Congo, Rep.	Ethiopia	Mongolia
Australia	Colombia	Guatemala	Togo	Russian Federation
Austria	Costa Rica	Honduras	Zimbabwe	Vietnam
Chile	Cuba	India	Liberia	Brunei Darussalam
Finland	Dominican Republic	Kenya	South Sudan	Kazakhstan
France	Algeria	Morocco	Gambia, The	Uzbekistan
Japan	Ecuador	Nigeria	Niger	Kyrgyz Republic
Korea, Rep.	Gabon	Sudan	Yemen, Rep.	Türkiye
The Netherlands	Iraq	Senegal	Tanzania	Israel
Norway	Jamaica	El Salvador	Niger	Lebanon
New Zealand	Mexico	Zambia	Liberia	Poland
Sweden	Mauritius	Pakistan	Somalia	Romania
Italy	Panama	Bangladesh	Rwanda	Czech Republic
Luxembourg	Peru	Sri Lanka	Uganda	Hungary
Panama	Tunisia	Indonesia	Malawi	Ukraine

	South Africa	Philippines	Chad	Azerbaijan
	Thailand	Egypt, Arab Rep.	Syrian Arab Republic	Belarus
	Malaysia			
	Iran, Islamic Rep.			
	Jordan			
	Bulgaria			