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Assessing the role of ecological innovation and economic growth in enhancing educational performance: evidence of BRICS countries

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ABSTRACT

Science symbolises education as an integral element in attaining environmental sustainability. Even after having elite-level human intelligence, this universe faces adverse effects of ecological deprivation. Therefore, this study specifically investigates the role of ecological innovation and economic growth on educational performance in BRICS nations. The present study selected the recent year's data of BRICS nations to explore the repercussions of ecological innovation and the countries' GDP income, and chooses the potential statistical technique name CS-ARDL method. In addition, this study uses other testing tools such as the CD test, unit root analysis tests, Westerlund and Edgerton test, and Bai and Silvestre-I-Carrion cointegration test to explore the role of these variables on educational performance. The estimated outcomes of the unit root test and CD test signify the structural breaks and heterogeneity in the data, but later Pesaran and Yamagata (2008) test resolved the relative issues. Therefore, long-run and short-run analyses of the CS-ARDL method identified the positive and significant affluence of ecological innovation (GIN) and economic growth (GDP) on educational performance (EDU). Thus, some dynamic policies are introduced in the below section to nourish the educational system of BRICS countries with the help of ecological innovation and economic progression.

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1. Introduction

In the forthcoming ages, this universe will be loaded with incessant innovatory revolutions; as Joseph Schumpeter cites in economic development theory, innovation is the imperious driver in attaining economic and financial growth (Blok, 2021). Eventually, enhancement in modernisation and industrialisation depends upon the rate of innovatory inventions that upgrade economic effectiveness and transform the old version of market processing. Despite the positive developments, innovative advancements bring difficulties and perplexities together (Surkhali & Garbuja, 2020). For instance,

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innovations encourage the consumption of fossil fuels and non-renewable energies that intensify the adverse effect of environmental quality (Ibrahim et al., 2022). Another scholar nurtures its voice against non-friendly innovations that are the apparent reasons behind environmental unsustainability (Assi et al., 2021). Due to this, policymakers and inventors incorporate the concept of go green in their developments to preserve the organic environment for living beings. Hence, according to Kiefer et al. (2019) preliminary act to transverse into green innovation, also referred to as ecological innovation, is concerned with the human intellect, which refers to capabilities, abilities, knowledge, and skills to innovate economically friendly developments. Therefore, Mehmood (2021) demonstrated that educationalism is a substantial component in accelerating innovations that enrich market proficiencies and innovate green eco-systems to nourish human intellect.

To this extent, numerous authors (Assi et al., 2021; Bratianu et al., 2021) verified that economic progress and ecological innovation boosted the readiness in educational practices. The significance between ecological innovation and educational performance is undeniable, as (Yang et al., 2022) stated that eco-compatible technologies are the repercussions of high education. The dynamic growth of ecological innovations introduced ultra-modern ways to accommodate systematic and sustainable education in the developed region significantly. However, energy consumption still increases due to unnecessary travelling trips to study abroad (Davis & Knight, 2021). Likewise, in the Paris agreement 2015, national authorities were commanded to impose public awareness courses through educational programs to minimise ecological uncertainties; after this, visible and positive modification is observed in educational performance (Blaskó et al., 2022). Without arguing, educational institutions may not only alter the academic background and pay or status; however, mould the whole society to act and reason to condemn the world as a deficit eco-accommodating nature. Also, Yang et al. (2022) suggested increasing educational resources that promote ecological innovations to minimise the ecological footprint. Similarly, Shaturaev (2021) demonstrated the positive escalation in green energy resources in Indonesia due to the quality education earned by employees through online scholarship programs. Moreover, using innovative learning tools not only creates easiness in teaching and learning but also intensifies employees' intelligence quotient to perform sensibly in their respective organisations. In this concern, Coman et al. (2022) addressed the institutional heads to adapt ecological innovations to enhance adequate living standards.

Subsequently, scholars perceived that innovative learning procedures develop strong acumen to survive in the fourth industrial revolution era (Blok, 2021). Thus, ecological innovation directly or indirectly influences education performance, like developed countries are eager to adopt the optimised versions of education. In contrast, unindustrialised nations are still struggling to upgrade their literacy rate. However, the manifestation of ecological innovations works wonderfully in all professions, as if every institution of specific occupations chooses green methodologies and equipment to maintain business sustainability (Aboramadan, 2022). Additionally, noted that effective and efficient measures for controlling the degraded environment can be secured after enabling the sustainable aspects for better education. In their study, Marra and Colantonio (2021) explain the positive significance of education on environmental quality and declare this factor as the positive cross-cutting effects on different eco-friendly externalities. Zahra (2021) also pointed out that because of the appropriate application of green ecological innovations, future generations learned and grabbed the knowledge to invent nature-oriented goods and services that were later declared significant assets to improve economic growth. Ultimately, past explorations of Hsu et al. (2021) investigated that aiding higher education funds to develop sustainable ecological innovations expands economic growth.

Moreover, the relationship between economic growth and educational performance is widely found in earlier studies because through the quintessence of education, several economies upgraded their entire business structure (Zhang et al., 2021; Maneejuk & Yamaka, 2021) and attained a sustainable position in the long-run equilibrium. Like in prior ages, neglection towards green educational practices increased the adverse effects of energy exploitation but now acknowledgment of green innovation while delivering the lectures condemns technology manufacturers towards non-renewable resources (Diebolt & Hippe, 2022). In another scenario, during the period of COVID −19 educational institutions suffer a lot, but innovative developments persuade the education system to convert to electronic means and escalate its market competitiveness (Islam et al., 2021). More than that, Hao et al. (2019) infer that highly polluted economies should invest a more significant share of capital in educational services, clean energy, and green technology to heighten their economic growth for a long period. As per Li et al. (2022), Russia and Japan adopted the green procedures of providing education to lower and higher-level students to level up their eco-centric economic growth by mitigating the emission of carbon dioxide.

Indeed, educational performance is a versatile factor that usually represents a positive affiliation with economic growth (Zafar et al., 2022). Hence, a sensible and comprehensive framework is needed to educate the citizens and monitor their educational performance because people are the real asset to growing economic productivity. For instance, BRICS nations verified the significance of economic growth on higher education by stating the technical and agricultural developments after sanctioning SDG goals implemented by their knowledgeable employees (Rasool et al., 2021). Once Li et al. (2021) stated that BRICS countries, i.e. (Brazil, Russia, India, China, and South Africa) are the emerging nations that face the adverse consequences of a low educational environment in the form of non-organic practices. Nevertheless, circumstances regarding education have improved a lot after the deceleration of a positive relationship between economic growth and educational performance (Chen et al., 2022). Still, emerging nations do not mainly focus on the education factor to upgrade their economic sustainability. Also, these nations are the leading economies that consume excessive energy and deteriorate the environment most. Thus, it is necessary to awaken emerging nations Like BRICS countries to personalize effective and competent educational systems and secure their economies from the repercussion of illiteracy. Here the contribution of the present study lies in that several authors insist on nourishing the educational system; however, as such, no effective measures are taken, especially in the history of BRICS nations. Through this study, a unique and practicable approach, i.e. ecological innovations and economic growth, is considered to enlighten the education mechanism previously not discussed. In this study, authors develop complete insights into education that are not only bound with the learning skills and knowledgeable attributes for economic sustainability but encompass the cultural and intellectual values that bring consistent change in daily operations (Zhang, 2021). Although BRICS nations mount up enough GDP per capita income through the sources of non-renewable energies without concerning China, India is the second and third largest emitter of carbon but heading tremendous economic growth (Zhang, 2021). Therefore, the factor of ecological innovation, i.e. green, is studied in light of educational performance. Additionally, few scholars investigated the BRICS nations and their educational performance thus via using the CS-ARDL method on recent statistical data clear identification of these variables. An account of the CS-ARDL method (Noureen et al., 2022) confirmed its reliability and accuracy in generalising the short and long-run results. Similarly, Ali et al. (2021) suggested the technique of cross-sectionally augmented distributed autoregressive lag (CS-ARDL), and the competitive strategies and policies regarding the discussed issue are determined.

The remainder of the paper resides in four sections. Section two comprises the recent literature on the variables such as ecological innovation and economic growth from the perspective of educational performance. Further, section three states the methodological approach based on which the fourth section presents the data analysis part. Lastly, section five explains the conclusion, Policy implication and limitations of the study.

2. Literature reviews

2.1. Ecological innovation and educational performance

Rapid emerging technologies and green innovation adaptation in every field and sector are being implemented for environmental sustainability (Feroz et al., 2021). This change affects all industries, including health, employment, etc. Similarly, educational institutions are embracing the green agenda and enhancing their performance with the help of the latest innovations, which will help ensure the ecological system's long-term stability (Cai et al., 2020). Even though, in present times, giant economies like European nations, the United Nations, and Arabian countries are aiding the funds for higher education to develop sustainable ecological innovations to improve the trade and industry of the specific countries (Arar, 2021). By influencing areas like environmental literacy, societal identities, and human capital, ecological innovation has a significant potential to improve environmental sustainability. It was shown in the paper by Nguyen Dang et al. (2022) that environmental literacy is essential for meeting educational, intellectual, and practical needs. The study found that GIN significantly contributes to fostering sustainable growth in employment, health, and education and that universities raise students' education levels. However, some earlier research found that the disparity in educational attainment has a detrimental effect on certain ecological performance factors. Ultimately, nations that offer various opportunities to acquire quality education may look forward to elevating their technical and mechanised productions (Zafar et al., 2022).

Similarly, Hao et al. (2019) conducted research in china. They discovered that the measurable difference between the educational level of local executives and returnees builds barriers to communications and knowledge, which ultimately affects ecological innovation (GIN) performance. Thus further, it is essential to augment and imply new strategies to educate the local executives. Latief et al. (2022) also emphasised the significance of raising the educational standard. The study considered education, ecological innovation (GIN), and other essential characteristics based on panel data collected from UFM countries between 2001 and 2016. The findings showed an inverted U-shaped relationship between urban population and environmental deterioration. However, it was shown that both high- and low-income countries experience a reduction in environmental deterioration due to expanding and implementing innovative educational methods. As a result, from various angles, educational attainment and performance are recognised as essential factors for the nation's growth. This identification is highlighted (Maneejuk & Yamaka, 2021) in 5-ASIAN countries. In order to better understand the crucial roles of ecological innovation (GIN) and education in Asia's heavily polluted countries, Li et al. (2022) presented a study. The study was carried out using the ARDL model, and the results suggest that an increase in ecological innovation lowers CO2 emissions by positively impacting academic achievement. It was shown that education also reduces carbon dioxide emissions in Russia and Japan. The idea of using green learning to attain a positive level of education for environmental sustainability was thus proved in this conclusion.

Furthermore, earlier works of literature have demonstrated the effectiveness of higher education. Data were gathered from Chinese A-share companies (He et al. 2021). The goal was to examine the significance of senior management's academic background. Senior management's involvement in academia was proven to have a favourable impact on corporate green innovation. Previous studies have effectively demonstrated the significance of effective teaching, which organisations can play by implementing ecological innovations. Higher education organisations are more likely to focus on environmental concerns (Benayas et al., 2002). In order to determine the function of green work commitment as a mediator between green human resource administration and higher education, Aboramadan (2022) performed a study using the social exchange theory. The conclusions clearly show that greater education and GHRM positively impact environmental outcomes. In a parallel manner, Nuryakin & Maryati (2022) probed the impact of owner and manager education on green marketing performance through a study conducted on 223 SMEs in Batik. It was rationally established that integrating environmental considerations into educational activities improves learning, which fosters green innovation and advances green marketing efforts for the expansion of businesses and organisations. The overall achievement of green product innovation and marketing enactment depends on green innovation and competitive advantages.

Additionally, prior studies concentrated on offering ways to achieve a higher degree of knowledge. Browning and Rigolon (2019) collaborated to find the effect of green spaces on educational performance. The findings of their study demonstrated that preparation exams, end-of-semester grades, and green environments, such as those found close to educational institutions, are all good indicators of improved academic achievement. The linkage between educational performance and green innovation is found to be interconnected. In order to determine the connection between higher education and the innovative environment, Cai et al. (2020) presented the study based on 16 publications read from numerous perspectives. The findings showed a significant relationship between both variables in bringing the finest ecological changes. Peng's (2022) study proved that implementing an innovation-orientated strategy in china positively affects innovation and entrepreneurship education in colleges and universities. The study successfully offers reliable knowledge to suggest a collaborative approach to teaching entrepreneurship education. The study concluded with a recommendation to examine the current educational model using ecological innovation. Generally, Islam et al. (2021) stated that through the sources of globalising engineers and energy manufacturers make the most from ecological advancements; for example, they change their traditional approach to a modernised approach by implementing the technicalities of higher education and also learning green practices to combat the ecological challenges recently faced regarding the quality environment.

As per the factual studies mentioned above, it is analysed that ecological innovation has a predominant role in higher education engagement (Davis, & Knight, 2021; Yang et al., 2022). Therefore, the new educational approaches are more likely to contribute to modernisation and positively influence all facets of society (Kiefer et al., 2019). However, these two variables are still neglected by the governments of BRICS nations; thus, this study add-on some potential theoretical and empirical findings on ecological innovation and educational performance determinants.

2.2. Economic growth and educational performance

The fundamental aim of the economies is to gain prosperity in the global market. Therefore, due to this emergence of urbanization, economic activities increases; thus, advancement and technical transformation in every sector are getting more evolved and noticeable (Zhang & Dilanchiev, 2022). According to Coman et al. (2022), a significant boom is observed in the education domain whenever economic growth intensifies. Since it is clear that GDP has a significant impact on sustainability, employment, health, and education, numerous studies have concluded that education plays an inevitable in economic growth. However, the education degree itself demands a lot of use (Sarwar et al., 2021). Diebolt and Hippe (2022) argued that practical and contemporary education, human capital, and innovation are essential for economic development to bring about long-lasting improvements in the world economy. Moreover, Jorgenson and Fraumeni (2020) collaborated in the literature to highlight the need to invest in people for their better development and future. The objective was to assess how investing in education affected American economic growth. The study concluded that investing in education has been proven essential for the nation's economic growth as the employment rate rises with educational attainment. This context was again discussed in the study of (Blaskó et al., 2022), where the positive influence of educational practices seems obvious when modernisation occurs.

Similarly, in 11 former European states, a research study by Coman et al. (2022) was done. The goal was to scrutinise how government investment in education affects economic growth. The results showed that public expenditure on education has good and significant results that directly impact the economy. Additionally, the implications were made to raise educational standards. In addition, Zhang et al. (2021) research supported the hypothesis that public spending on education, research, and development boosts the company's economy. Furthermore, it was noted that low-income nations could not make the same contributions to education as high-income nations due to the economic downturn. The study used the generalised moment's approach and the DEA method to collect data from the BRI participant nations between 2008 and 2018. Consequently, it was determined that public spending on R&D and education is boosting the green economy trend. The positive effects of public spending on technical innovation also help raise the nation's GDP (Xing & Fuest, 2018).

The parallel viewpoint was noted by Chege et al. (2020) that how little education and expertise are needed to gain ICT skills. Regarding the previous statement, the research demonstrated that economic growth is crucial for the nation's future prosperity and society in terms of educational attainment. In their research article, Hanushek and Woessmann (2021) made it abundantly evident that education drives the economy and that quality education leads to innovation and increased knowledge. The report also concluded that not all schools educate students and raise them in the same ways as others while reinforcing the green investment. Higher education is the focus of attention because it is most successful at competing in the global market. Agasisti and Bertoletti (2020) looked into higher education's role in fostering economic growth. The information was collected over 18 years from 284 different European regions. Nevertheless, the results showed a significant impact when decisions were taken to implement a STEM subject policy and other methods, like hiring and investing in teachers to broaden kids' interests. Thus, it can be seen from earlier studies that there is a positive and direct correlation between educational achievement and economic growth.

Although Jamel et al. (2020) also examine the association between education and economic development. Twenty-eight middle-income nations made up the sample that was gathered. The results confirmed the hypothesis and revealed a significant correlation between the two variables. Because families, instructors, and educational institutions, as well as the government, are all responsible for providing high-quality education. In their chapter, Hanushek, and Woessmann (2020) explore the significance of high-quality education. The report made a brief case for why more emphasis should be placed on maintaining educational standards and that education should be delivered with a focus on quality rather than quantity. From a basic point of view, it is possible with the assistance of the economy and investments. Liao et al. (2019) offered a study to investigate the causation between investment in educational sectors and the positive result of economic growth. Similar to other studies, this one came to the same conclusion on the positive effects of local financial investment on the country's economy and sustainability. Likewise, technology helps to improve educational opportunities for everybody (Chen, 2022). Donou-Adonsou (2019) collected data from 45 countries to find the effect of telecommunication on economic growth with better access to education and its comparison with less access to education. The findings indicated that countries with better access to education are more likely to use telecommunications and mobile phones to boost their GDP.

Over the above decelerations, the relationship between economic growth and education is significant. In correspondence to this, Sarwar et al. (2021) assimilated similar views about economic growth in enhancing educational performance. Such significance motivates scholars to enlighten the economies to concentrate on educationalism when heading towards economic growth (Mehmood, 2021). Although the practicalities of education in developing nations like BRICS countries are still overlapped due to fierce market competition, thus the absence of a green educational system leads to adverse effects of environmental degradation. In this vein, the present study accumulated the relevant studies on educational performance and economic growth to clear the insights of the emphasised policymakers of BRICS nations.

3. Estimation approach

3.1. Unit root testing

It is beneficial to check cross-sectional dependence before testing the unit root process. To cope with cross-section dependence, use applicable unit root tests from the first, second, and third generations of tests. So, we chose to examine the cross-sectional dependence as the foremost step of our research. CD is related to financial integration, economics, residual interconnectedness, common stocks (oil price stock), the global financial crisis, and others. Pesaran (2015) gave the Cross-sectional dependence test, which enables the detection of the issues faced by CD. The problem arising in cross-sectional dependence is essential to be tackled as it can give rise to other problematic developments like distortion of sizes or cointegration results (Salim et al., 2017; Westerlund, 2007). After corroborating, the CD test findings were obtained.

A system is in place to verify the stationarity of panel data. First-generation, second-generation, and third-generation panel unit root tests are the primary groups into which the prevailing literature on nonstationarity in the data set is categorised. Numerous researchers have worked on this problem. For instance, Levin et al. (2002) addressed the nonstationary issue in the homogenous nature pane data (Choi, 2001). In contrast, heterogeneous panel data with a similar problem is addressed by (Im et al., 2003). The second-generation unit root tests created by Pesaran (2007), Choi (2006), and Moon and Perron (2012) not only address the dispute of heterogeneity but also resolve the issue of cross-section dependence between units, in contrast to Levin et al. (2002) and Maddala and Wu (1999). However, first and second-generation fail to perform better and lose power if there is a chance of structural breakdowns in the chain due to regional or international events. Third-generation panel unit root tests in the presence of structural breaks not only address potential structural breakdowns in panel data but also consider variability and cross-section dependence issues (Bai & Carrion-I-Silvestre, 2009). This work adopts the methodologies of Bai and Carrion-I-Silvestre (2009) and Pesaran (2007) to address the issue of nonstationarity with cross-section dependency because the use of first-generation panel unit root tests is invalidated by the presence of cross-section dependence (Jalil, 2014). Additionally, we apply (Llu's Carrion-i-Silvestre et al., 2005) test to account for the impact of structural breaks in intervals for each cross-section.

3.2. Cointegration

The modernised and recent version of Swamy's test (1970) by Pesaran and Yamagata (2008) has been used to determine whether the slope is homogenous or whether heterogeneity is present in the slope. This has been tested after the determination of unit root or stationarity. The test's null hypothesis considers that the slope parameters are homogeneous and heterogeneous. Due to the presence of cross-section dependency, the first-generation cointegration approaches by Pedroni (2004) and Westerlund (2005) fail to offer adequate estimations because of size things distortion (McCoskey and Kao, 1998 and Larsson et al., 2001). No cross-section dependence among the cross-sections under discussion is assumed by Pedroni (2001) as well as Kao et al. (1999) failed to claim any CD under consideration. We employ heterogeneous estimating techniques proposed by Westerlund and Edgerton (2008) and Banerjee and Carrion-i-Silvestre (2008) in the data showing the existence of CD, heterogeneity, and nonstationarity problems. These techniques address the earlier problems and spot structure defects when cointegration is present. While Westerlund (2007) takes into mind the problem of variable slope parameters and cross-section dependence, he neglects to consider the impact of potential structural breaks, which would prevent the null hypothesis of no cointegration from being rejected. In contrast to the first and 2nd generation tests, Westerlund and Edgerton's (2008) methodology deals with potential structural failures at various sites for each cross-section in addition to cross-sectional dependence, heterogeneity of slopes, and correlated errors occurring serially. Another comparable method, based on the CCEMG method (Common Correlated Effects Mean Group) proposed by Banerjee & Carrion-i-Silvestre (2017), is utilised in the current study to examine the co-integrating relationship between the given variables. This method addresses heterogeneity, strong as well as a CD, panel data, which is nonstationary, and parameters that may be reliably calculated within the context of regression analysis.

3.3. Cs-ARDL (cross-sectionally autoregressive distributed lags)

The problem of Cross section dependence may appear due to the global financial crisis and oil prices, and numerous aspects would affect it. Thus the occurrence of CD is noticed in the data set. This can also provide adverse effects if an undetected common factor correspond with regressors (Yao et al., 2019). Here, CS-ARDL can overcome the issue of slop heterogeneity and cross-section by using the dynamic common correlated effect introduced by (Çoban & Topcu, 2013), which the conventional estimations techniques are not capable to.

For this, the opening equation of CS-ARDL is given below

$$U_{k,t} = \sum_{I=0}^{p_G} \gamma_{I,k,} G_{k,t-1} + \sum_{I=0}^{p_H} \beta_{I,k,} H_{k,t-1} + \varepsilon_{k,t}$$

We found Eq. (3) as the ARDL method, and it will be followed by Eq. (4), which may help to get a satisfactory result by providing the average of each cross-section regressor as well as also helps to recover from that negative impact which was caused by cross-section dependence (Chudik & Pesaran, 2015), whereas Eq. (7) proves unfit to give satisfactory results in the existence of Cross section dependence.

$$U_{k,t} = \sum_{I=0}^{p_G} \gamma_{I,k,} G_{k,t-1} + \sum_{I=0}^{p_H} \beta_{I,k,} H_{k,t-1} + \sum_{I=0}^{p_\gamma} \alpha'_{k,} K\overline{Y}_{k,t-1} + \varepsilon_{k,t}$$

Average of both dependent and independent variables $\overline{Y}_{t-1} = (\overline{U_{k,t-1}, \ H_{k,t-1}})$ under consideration of $p_U, p_G, p_H,$ proof to be not ideal to each other. Where $U_{i,t}$ indicates the dependent variable, for example, educational performance, and $H_{k,t}$ indicates the independent variable, for example, ecological innovation and economic growth, energy consumption, and Human capital index. Indicates the average of Cross section without any artificial trend to avoid any spill-over effect of Cross section dependence. CS-ARDL then estimates the long-run figure from the short-run figure, as well as with the mean group. Hence it gives the results below

$$\pi_{CS-ARDL,k} = \frac{\sum_{K=0}^{pH} \hat{\beta}_{I,K}^{\quad PG}}{1 - \sum I = 0} \gamma_{I,K}$$

The calculation of the Mean Group is arranged below:

$$\pi_{MG} = \frac{1}{N} \sum_{k=0}^{N} \hat{\pi}_k$$

The assessed equation of the short-run is mentioned below:

$$\Delta U_{k,t} = \vartheta_k [G_{K,t-1} - \pi_K H_{k,t}] - \sum_{I=1}^{PG-1} \gamma_{I,K}, \Delta_I G_{k,t-1} + \sum_{I=0}^{PH} \beta_{I,k}, \Delta_I H_{k,t} + \sum_{I=0}^{p_Y} \alpha'_{k,} I\overline{Y}_{k,t} + \varepsilon_{k,t}$$

where

$$\Delta_I = t - (t-1)$$

$$\tau_K = -\left(1 - \sum_{I=1}^{pG} \gamma_{I,k}\right)$$

$$\hat{\pi} = \frac{\sum_{I=0}^{PH} \beta_{I,k}}{\tau_k}$$

$$\overline{\hat{\pi}} = \frac{1}{N} \sum_{k=0}^{N} \hat{\pi}_k$$

For CS-ADRL, the same as PMG (Pooled Mean Group), this study uses the ECM (-1), which means that it maintains the speed towards the equilibrium or adjusts the spell it takes for the economy to reach the equilibrium point.

4. Data analysis

Table 1 reported the cross-sectional dependence analysis results based on Pesaran's (2015) criteria. This specific test is significant to minimise the appearance of bias cointegration (Churchill et al., 2019). As per the results, rejection of the null hypothesis is confirmed for all variables, i.e. educational performance (EDU), ecological innovation

Table 1. Results of cross-sectional dependence analysis.

Variable	Test statistics (p-values)
EDU	28.125*** (0.000)
GIN	21.019*** (0.000)
GDP	37.116*** (0.000)
HCI	22.434*** (0.000)
ENE	49.989*** (0.000)

Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively, whereas the values are in parentheses contains P-values.
EDU represents higher education enrolment, GIN explains green technology innovation, GDP denotes Gross domestic product, HCI reflects Human capital index, and ENE symbolises Primary Energy consumption.
Source: Author's Estimations.

(GIN), economic growth (GDP), and human capital index (HCI), and energy consumption (ENE) at a significance level of 1%, 5%, and 10%. Furthermore, to check the emergence of stationarity in the data, we employ two estimations of unit root tests, like Pesaran (2007) and Bai and Carrion-I-Silvestre (2009), in table 2. Here, in table 2, the empirical investigation of the unit root test is conducted under the presence of heterogeneity, structural breaks, and stationarity problems. Thus both tests reject the occurrence of a null hypothesis only for Bai and Carrion-I-Silvestre (2009) of nonstationarity or unit root in the panel data. In contrast, Pesaran (2007) declared stationary at the level position of all factors. However, this identification encourages authors to employ the technique of first-order differencing where empirical findings accept the null hypothesis in the existence of CD, structural breaks, and heterogeneity problems; this cycle confirms the stationarity of all variables at first-order difference or integrated at I(1).

After resolving the cross-sectional issues and steps of unit root testing, this study employs the improved version of Swamy's (1970) test by Pesaran and Yamagata (2008) in

Table 2. Results of unit root test with & without structural break Pesaran (2007).

	Level I(0)				First Difference I(1)	
Variables	CIPS	M-CIPS			CIPS	M-CIPS
EDU	−3.190***	−6.009**			–	–
GIN	−6.007***	−3.183**			–	–
GDP	−4.128***	−5.051**			–	–
HCI	−5.031***	−4.160**			–	–
ENE	−3.169***	−6.005**				
Bai and Carrion-i-Silvestre (2009)						
	Z	P_m	*P*	*Z*	P_m	*P*
EDU	0.163	0.361	21.014	−4.155***	3.164***	76.143***
GIN	0.349	0.280	17.158	−6.009***	6.010***	91.008***
GDP	0.270	0.199	20.020	−3.182***	4.139***	55.196***
HCI	0.185	0.244	16.192	−5.099***	5.100***	82.071***
ENE	0.227	0.156	22.006	−4.173***	3.181***	64.162***

Note: The level of significance is determined by 1, 5, and 10% indicated through ***, ** and * respectively. For Bai & Carrion-i-Silvestre (2009) test, 1, 5 and 10% critical values (CV) for *Z* and *Pm* statistics are 2.326, 1.645 and 1.282, while the critical values (CV) for *P* are 56.06, 48.60 and 44.90, separately.
Source: Author's Estimations.

Table 3. Results of Slope heterogeneity analysis.

Statistics	Test value (P-value)
Delta tilde	48.141*** (0.000)
Delta tilde Adjusted	52.129*** (0.000)

Source: Author estimation.

table 3. The prime purpose of this test is to identify the existence of heterogeneity and homogeneity in the panel data. If the figures show the approval of the null hypothesis, the data is said to be homogenous. Otherwise, rejection of the null hypothesis indicates the manifestation of heterogeneity in the data. Table 3 represents the heterogeneity in the data, which means the null hypothesis is rejected at 1%, 5%, and 10%. Another estimated test of panel cointegration proposed by Westerlund & Edgerton (2008) is reported in Table 4. This test checks the presence of cointegration among the variables by using the no break, mean shit, and regime shift factors. Here all columns of the respective factors rejected the null hypothesis and showed the cointegration among the variables such as educational performance (EDU), ecological innovation (GIN), economic growth (GDP), human capital index (HCI), and energy consumption (ENE) while scrutinising the data of BRICS nations.

Proceeding to Table 5, the further elaboration of cointegration analysis under the proposed perception of Banerjee and Carrion-i-Silvestre (2017) is mentioned in Table 5. Ultimately the present test confirms the cointegration between the determinants, for example, educational performance (EDU), ecological innovation (GIN), economic growth (GDP), human capital index (HCI), and energy consumption (ENE), while scrutinising the data of BRICS nations are co-integrated. The identical results of Westerlund and Edgerton (2008) and Banerjee and Carrion-i-Silvestre (2017) among the variables of education and economic growth are found in the study. Here the values are significant at 1%, 5%, and 10% for the total sample of BRICS nations. This indication proceeds the analysis to investigate long-run and short-run results with the help of the CS-ARDL method.

Table 4. Results of Westerlund and Edgerton's (2008) panel cointegration analysis.

Test	No break	Mean shift	Regime shift
$Z_{\varphi}(N)$	−8.402***	−8.329***	−8.977***
P_{value}	0.000	0.000	0.000
$Z_{\tau}(N)$	−6.151***	−6.068***	−6.145***
P_{value}	0.000	0.000	0.000

Source: Author estimation.

Table 5. Results of Banerjee and Carrion-i-Silvestre (2017) cointegration analysis.

Countries	No deterministic specification	With constant	With trend
Dependent Variable: EDU			
Full Sample	−6.003***	−3.164***	−4.138***
Brazil	−4.155***	−5.082***	−6.011***
Russia	−5.118***	−4.149***	−3.174***
India	−3.169***	−6.010***	−5.060***
China	−4.125***	−4.145***	−4.159***
South Africa	−3.170***	−3.172***	−6.001***
Turkey	−5.082***	−4.150***	−4.168***

Source: Author estimation

Table 6. Results of CS-ARDL analysis (long run).

Variables	Coefficients	t-statistics	p-values
GIN	0.175***	5.005***	0.000
GDP	0.508***	4.146***	0.000
HCI	0.351***	5.872***	0.000
ENE	0.283***	4.178***	0.000

Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively.
Source: Author's Estimations.

In Table 6, the accumulated estimations of the long-run are shown underneath the heading of coefficient, t- statistics, and p-values. The present study uses the support of HCI (human capital index) and ENE (energy consumption) to explore the actual income holders and energy consumption rate in the BRICS nations, respectively. However, both these variables are significant and represent the positive affiliation in the longer run with educational performance. Such indications related to innovation and education are also investigated in the study (Lo & Tian, 2020). Moreover, the GIN (ecological innovation) reports a coefficient value of 0.175*** with a significance level of 1% in the longer run; this means a 1% increase in ecological innovations and educational performance increases by 0.175 in BRICS countries. This interprets that BRICS countries must invent educational perspective innovations that will be highly modernised as well as ecologically friendly. This evolution positively affected the entire world. According to Li and Ullah (2022), BRICS states are progressively innovative in emerging green technologies. Thus the impact of this on the educational system is positive and significant. Another scholar, Ahmad et al. (2021), explored the influence of green innovations on educational performance in G7 countries. Their results are similar to the present one, i.e. positive and significant improvements shown in educational programs with present study results.

Likewise, the component of GDP possesses a coefficient value of 0.508 with a significance point of 1%; this shows that in BRICS countries, whenever GDP grows by 1%, educational performance is boosted by 0.508% in the long run analysis. In this vein, the gross domestic product of BRICS nations positively influenced the educational performance of their citizen. Thus, Wang et al. (2021) demonstrated that countries like China and Russia struggle to mitigate energy consumption through increased awareness tactics towards green industrialisation. Pathak and Shah (2019) conducted their study in a similar context; their estimations identified that China, Russia, and India initiated numerous green wakefulness programs in every field of education to attain longer-run stability. Also, Stehlik (2018) explored the identical influence of economic growth on educational performance while exploring the carbon neutrality element in Nordic nations. While explaining the benefits of higher education, (Sharma et al., 2021) revealed the negative relationship between education and environmental externalities and the positive relationship between economic growth and environmental pollution.

After estimating the CS-ARDL longer run, Table 7 illustrates the statistical figures of sort run equilibrium concerning educational performance. Here crucial determinants of GIN and GDP represent the positive association with educational performance in short-run analysis considering the data set of BRICS countries. If we analyse separately, the component of GIN shows a coefficient value of (0.045***), this signifies that increased

Table 7. Results of CS-ARDL analysis (short run).

Variables	Coefficients	t-statistics	p-values
GIN	0.045***	3.355***	0.000
GDP	0.168***	5.883***	0.000
HCI	0.093***	2.248***	0.034
ENE	0.042***	1.778***	0.081
ECM(-1)	−0.285***	4.483***	0.000

Note: ***, ** & * explain the level of significance at 1%, 5% and 10% respectively.
Source: Author's Estimations.

ecological innovations support the better quality of educational performance in BRIC countries. For instance, Shoaib et al. (2021) emphasised that policymakers initiate a green educational system's intellectual and practical practice by using eco-friendly technologies to sustain a nature-oriented atmosphere. In parallel with the mentioned results, the investigation of (Zahra, 2021; Hanushek & Woessmann, 2020) discussed the same ideology of education and innovation. They analysed the positive change in the agriculture and industrial department to abate the environmental uncertainties only because of the implications of knowledge and skills. Thus education performance is enlightened if ecological innovation increases (Bratianu et al., 2021) and (Chege et al., 2020) support the current results.

In the same way, the economic growth (GDP) of BRICS nations signifies the coefficient value of (0.168***). Thus, in BRICS countries such as Brazil, Russia, India, China, and South Africa, educational performance becomes more sustainable and eco-oriented whenever the rise in GDP occurs. A parallel identification was explored in the study (Li & Ullah, 2022). Also, Diebolt and Hippe (2022) second the positive affirmation of economic growth on the education intuition of European nations. In addition, newly invented green technologies create easiness in achieving higher education, as stated by (Hsu et al., 2021). Besides, these two components, supportive variables of ENE and HCI, signify the positive correlation with educational performance in short-run analyses of BRICS countries.

5. Conclusion

In a nutshell, science embodies the significance of education in every phase of human life. Similarly, environmentalists consider education as an integral element in attaining environmental sustainability. Even after having elite-level human intelligence, the universe faces adverse effects of ecological deprivation due to improper mechanisms of raising prevalent economies. In this concern, this study aims to investigate the role of ecological innovation and economic growth on educational performance in BRICS nations. Mainly, BRICS countries are the fastest growing economies of the world and influence the earth's natural habitats tremendously; that is why the present study selected the recent year's data of BRICS nations to investigate the repercussions of ecological innovation and GDP income of the mentioned countries. However, the current study chooses the potential statistical technique name CS-ARDL method. It uses other testing tools such as the CD test, Unit root analysis tests, Westerlund and Edgerton test, and Bai and Silvestre-I-Carrion cointegration test to explore these variables' role on educational performance. The estimated results of the unit root test and CD test signify the structural breaks and heterogeneity in the data, but later Pesaran and Yamagata (2017) test resolved the relative issues. Therefore, long-run and short-run analyses of the CS-ARDL method identified the positive and significant affluence of ecological innovation (GIN) and economic growth (GDP) on educational performance (EDU).

To sum up the CS-ARDL results in the long run and short, this study accumulated the support of two more variables, i.e. energy consumption (ENE) and human capital index (HCI). Both variables indicate a positive and significant association with education performance. At the same time, the variables of ecological innovation and economic growth indicate positive and significant affluence on educational performance by representing the values of (0.175***) and (0.508***), respectively, in the long run. Similarly, short-run analysis interprets the exact estimations but with different statistical figures. Therefore, the analyses of CS-ARDL confirm that in BRICS nations, green and eco-centric advancement and urbanisation bring efficiency plus betterment in educational performance. However, these countries are highly optimised and industrialised, and these nations' governments still show negligence and inconsistency in upgrading the educational departments concerning a green economy. Thus, some dynamic policies are introduced in the below section to nourish the educational system of BRICS countries with the help of ecological innovation and economic progression.

5.1. Policy implications

In order to sustain the ecological innovation in BRICS countries, some multi-disciplinary strategies are compulsory to implement in the education sector to flourish the performance of the green educational system of BRICS nations. As per the results, ecological innovations are incentive-based innovations from educational performance. Thus, policymakers should convince the governments of China and India to integrate educational services via funding online courses and free online certification for the employees of industrial and agriculture sectors to convert their set-ups into green operations. As these two states of BRICS are highly carbon-intensive countries thus, this policy not only reduces the transportation cost but decreases the travelling energy consumption of the students, which is more significant in number. Also, a collaboration of these entities brings stability to their political conflicts. Secondly, to improve the better educational performance, developed nations of BRICS countries implant their specialised learning software of ERP, SAP Litmos, and Tovuti to gain competent knowledge of the entire world while subsidising the consumption of non-renewable energies. Thirdly policymakers of BRICS nations must incorporate the educational sessions on 'building a green economy' to the under and postgraduate students who are future engineers and technical innovators. This is how the longevity of green eco-systems can sustain in BRICS countries.

Furthermore, based on the positive and significant association between economic growth and educational performance observed in BRICS countries, policymakers must establish more educational institutions that emphasise more on practice-based learning rather than theory-based learning, for instance, smart skills to utilise natural resources, how to develop less carbon explosive machines and engines, green concepts of cost-cutting in a supply chain system. These educational practices bring sustainability to environmental externalities and stabilise economic progression. The second initiative that must impose by policymakers is to restrict manufacturers and developers of modernised innovations from using an excessive amount of non-renewable resources and recommend they gain some educational testimonial in making ecologically friendly innovations to upgrade the GDP of BRICS economies. Third, Ahmad and Zheng (2021) suggested that BRICS countries prevail free educational services till intermediation because the population of China and India rapidly increases; thus, the utilisation of natural habitats increases, which increases the ecological footprint ratio. Thus, while educating the entire youth, more occupational services and businesses originate in the market, and hence employment ratio increases, directly raising the economic growth of BRICS nations. Therefore, these mentioned guidelines and strategical approaches may enhance the educational performance of BRICS states based on which speedy transformation towards a green eco-system is patent.

5.2. Limitations and future directions

Similar to every other study, contemporary research possesses multiple limitations. For example, here, the data is extracted from the BRICS nations, and if more regions are considered, a more reliable and authentic elaboration on specific variables is generated. Additionally, this study narrows its boundaries with three main components, i.e. educational performance, ecological innovation, and economic growth; if, in the future, the essence of more econometric factors is incorporated, a more dynamic picture of analysis has emerged. Finally, the study confines to the CS-ARDL method; however, this is a unique and competent technique but looks more substantial if the quantile-based, i.e. the QARDL method, is used to provide a more detailed examination of respective variables.

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References

Aboramadan, M. (2022). The effect of green HRM on employee green behaviors in higher education: The mediating mechanism of green work engagement. *International Journal of Organizational Analysis*, *30*(1), 7–23. https://doi.org/10.1108/IJOA-05-2020-2190

Agasisti, T., & Bertoletti, A. (2020). Higher education and economic growth: A longitudinal study of European regions 2000–2017. *Socio-Economic Planning Sciences*, *100940*, 1–18.

Ahmad, M., & Zheng, J. (2021). Do innovation in environmental-related technologies cyclically and asymmetrically affect environmental sustainability in BRICS nations? *Technology in Society*, *67*, 101746. https://doi.org/10.1016/j.techsoc.2021.101746

Ahmad, M., Jiang, P., Murshed, M., Shehzad, K., Akram, R., Cui, L., & Khan, Z. (2021). Modelling the dynamic linkages between eco-innovation, urbanization, economic growth and ecological footprints for G7 countries: does financial globalization matter? *Sustainable Cities and Society*, *70*, 102881. https://doi.org/10.1016/j.scs.2021.102881

Arar, K. H. (2021). Research on refugees' pathways to higher education since 2010: A systematic review. *Review of Education*, *9*(3), e3303. https://doi.org/10.1002/rev3.3303

Assi, A. F., Isiksal, A. Z., & Tursoy, T. (2021). Renewable energy consumption, financial development, environmental pollution, and innovations in the ASEAN+ 3 group: Evidence from (P-ARDL) model. *Renewable Energy*, *165*, 689–700. https://doi.org/10.1016/j.renene.2020.11.052

Bai, J., & Carrion-I-Silvestre, J. L. (2009). Structural changes, common stochastic trends, and unit roots in panel data. *The Review of Economic Studies*, *76*(2), 471–501.

Banerjee, A., & Carrion-i-Silvestre, J. L. (2017). Testing for panel cointegration using common correlated effects estimators. *Journal of Time Series Analysis*, *38*(4), 610–636. https://doi.org/10.1111/jtsa.12234

Benayas, R., José, M., & Scheiner, S. M. (2002). Plant diversity, biogeography and environment in Iberia: Patterns and possible causal factors. *Journal of Vegetation Science*, *13*(2), 245–258. https://doi.org/10.1111/j.1654-1103.2002.tb02045.x

Blaskó, Z., Costa, P. D., & Schnepf, S. V. (2022). Learning losses and educational inequalities in Europe: Mapping the potential consequences of the COVID-19 crisis. *Journal of European Social Policy*, *32*(4), 361–375. https://doi.org/10.1177/09589287221091687

Blok, V. (2021). What Is Innovation?: Laying the Ground for a Philosophy of Innovation. *Techné: Research in Philosophy and Technology*, *25*(1), 72–96. https://doi.org/10.5840/techne2020109129

Bratianu, C., Stanescu, D. F., & Mocanu, R. (2021). Exploring the knowledge management impact on business education. *Sustainability*, *13*(4), 2313. https://doi.org/10.3390/su13042313

Browning, M. H., & Rigolon, A. (2019). School green space and its impact on academic performance: A systematic literature review. *International Journal of Environmental Research and Public Health*, *16*(3), 429. https://doi.org/10.3390/ijerph16030429

Cai, Y., Ma, J., & Chen, Q. (2020). Higher education in innovation eco-systems. *Sustainability*, *12*(11), 4376. https://doi.org/10.3390/su12114376

Carrion-I-Silvestre, J. L., del Barrio-Castro, T., & Lopez-Bazo, E. (2005). Breaking the panels: An application to the GDP per capita. *The Econometrics Journal*, *8*, 159–175.

Chege, S. M., Wang, D., & Suntu, S. L. (2020). Impact of information technology innovation on firm performance in Kenya. *Information Technology for Development*, *26*(2), 316–345. https://doi.org/10.1080/02681102.2019.1573717

Chen, H., Tackie, E. A., Ahakwa, I., Musah, M., Salakpi, A., Alfred, M., & Atingabili, S. (2022). Does energy consumption, economic growth, urbanization, and population growth influence carbon emissions in the BRICS? Evidence from panel models robust to cross-sectional dependence and slope heterogeneity. *Environmental science and Pollution Research International*, *29*(25), 37598–37616. https://doi.org/10.1007/s11356-021-17671-4

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance*, *20*(2), 249–272. https://doi.org/10.1016/S0261-5606(00)00048-6

Choi, I. (2006). Combination unit root tests for cross-sectionally correlated panels, chapter 12. In D. Corbae, S. N. Durlauf & B. E. Hansen (eds.), *Econometrics theory and practice: frontiers of analysis and applied research*, 311 (p. 333). Cambridge: Cambridge University Press.

Chudik, A., & Pesaran, M. H. (2015). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics*, *188*(2), 393–420. https://doi.org/10.1016/j.jeconom.2015.03.007

Churchill, S. A., Inekwe, J., Smyth, R., & Zhang, X. (2019). R&D intensity and carbon emissions in the G7: 1870–2014. *Energy Economics*, *80*, 30–37.

Coman, A. C., Lupu, D., & Nuţă, F. M. (2022). The impact of public education spending on economic growth in Central and Eastern Europe. *An ARDL Approach with Structural Break. Economic Research-Ekonomska Istraživanja*, 1–18.

Davis, K. A., & Knight, D. B. (2021). Comparing students' study abroad experiences and outcomes across global contexts. *International Journal of Intercultural Relations*, *83*, 114–127. https://doi.org/10.1016/j.ijintrel.2021.05.003

Diebolt, C., & Hippe, R. (2022). The long-run impact of human capital on innovation and economic growth in the regions of Europe. In *Human Capital and Regional Development in Europe* (pp. 85–115). Springer.

Donou-Adonsou, F. (2019). Technology, education, and economic growth in Sub-Saharan Africa. *Telecommunications Policy*, *43*(4), 353–360. https://doi.org/10.1016/j.telpol.2018.08.005

Feroz, A. K., Zo, H., & Chiravuri, A. (2021). Digital transformation and environmental sustainability: A review and research agenda. *Sustainability*, *13*(3), 1530. https://doi.org/10.3390/su13031530

Hanushek, E. A., & Woessmann, L. (2020). A quantitative look at the economic impact of the European Union's educational goals. *Education Economics*, *28*(3), 225–244.

Hanushek, E. A., & Woessmann, L. (2021). Education and economic growth. *Oxford Research Encyclopedia of Economics and Finance*. https://doi.org/10.1093/acrefore/9780190625979.013.651

Hao, Y., Fan, C., Long, Y., & Pan, J. (2019). The role of returnee executives in improving green innovation performance of Chinese manufacturing enterprises: Implications for sustainable development strategy. *Business Strategy and the Environment*, *28*(5), 804–818. https://doi.org/10.1002/bse.2282

He, K., Chen, W., & Zhang, L. (2021). Senior management's academic experience and corporate green innovation. *Technological Forecasting and Social Change*, *166*, 120664. https://doi.org/10.1016/j.techfore.2021.120664

Hsu, C. C., Quang-Thanh, N., Chien, F., Li, L., & Mohsin, M. (2021). Evaluating green innovation and financial development performance: mediating environmental regulation concerns. *Environmental science and Pollution Research International*, *28*(40), 57386–57397. https://doi.org/10.1007/s11356-021-14499-w

Ibrahim, R. L., Ozturk, I., Al-Faryan, M., A., S., & Al-Mulali, U. (2022). Exploring the nexuses of disintegrated energy consumption, structural change, and financial development on environmental sustainability in BRICS: Modulating roles of green innovations and regulatory quality. *Sustainable Energy Technologies and Assessments*, *53*, 102529. https://doi.org/10.1016/j.seta.2022.102529

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

Islam, M., Islam, M. S., Siddik, M. A. B., & Mousumi, S. S. S. (2021). *Analyzing the Cause of Students Reluctant to Participate in the Classroom: Machine Learning Approach* [Paper presentation]. 2021 10th International Conference on System Modeling & Advancement in Research Trends (SMART), December (pp. 484–488). IEEE. https://doi.org/10.1109/SMART52563.2021.9676223

Jalil, A. (2014). Energy–growth conundrum in energy exporting and importing countries: Evidence from heterogeneous panel methods robust to cross-sectional dependence. *Energy Economics*, *44*, 314–324. https://doi.org/10.1016/j.eneco.2014.04.015

Jamel, L., Ltaifa, M. B., Elnagar, A. K., Derbali, A., & Lamouchi, A. (2020). The Nexus between education and economic growth: Analyzing empirically a case of middle-income countries. *Virtual Economics*, *3*(2), 43–60. https://doi.org/10.34021/ve.2020.03.02(3)

Jorgenson, D. W., & Fraumeni, B. M. (2020). Investment in education and US economic growth. In *The US savings challenge* (pp. 114–149). Routledge.

Kao, C., Chiang, M. H., & Chen, B. (1999). International R&D spillovers: An application of estimation and inference in panel cointegration. *Oxford Bulletin of Economics and Statistics*, *61*(S1), 691–709. https://doi.org/10.1111/1468-0084.61.s1.16

Kiefer, C. P., Del Rio Gonzalez, P., & Carrillo-Hermosilla, J. (2019). Drivers and barriers of eco-innovation types for sustainable transitions: A quantitative perspective. *Business Strategy and the Environment*, *28*(1), 155–172. https://doi.org/10.1002/bse.2246

Larsson, R., Lyhagen, J., & Löthgren, M. (2001). Likelihood-based cointegration tests in heterogeneous panels. *The Econometrics Journal*, *4*(1), 109–142. https://doi.org/10.1111/1368-423X.00059

Latief, R., Sattar, U., Javeed, S. A., Gull, A. A., & Pei, Y. (2022). The environmental effects of urbanization, education, and green innovation in the Union for Mediterranean Countries: Evidence from quantile regression model. *Energies*, *15*(15), 5456. https://doi.org/10.3390/en15155456

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, *108*(1), 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7

Li, H., Khattak, S. I., & Ahmad, M. (2021). Measuring the impact of higher education on environmental pollution: New evidence from thirty provinces in China. *Environmental and Ecological Statistics*, *28*(1), 187–217. https://doi.org/10.1007/s10651-020-00480-2

Li, L., Li, G., Ozturk, I., & Ullah, S. (2022). Green innovation and environmental sustainability: Do clean energy investment and education matter? *Energy & Environment, 0958305X221115096*, 0958305X2211150. https://doi.org/10.1177/0958305X221115096

Li, X., & Ullah, S. (2022). Caring for the environment: How CO2 emissions respond to human capital in BRICS economies? *Environmental science and Pollution Research International*, *29*(12), 18036–18046. https://doi.org/10.1007/s11356-021-17025-0

Liao, L., Du, M., Wang, B., & Yu, Y. (2019). The impact of educational investment on sustainable economic growth in Guangdong, China: A cointegration and causality analysis. *Sustainability*, *11*(3), 766. https://doi.org/10.3390/su11030766

Lo, M. F., & Tian, F. (2020). Enhancing competitive advantage in Hong Kong higher education: Linking knowledge sharing, absorptive capacity and innovation capability. *Higher Education Quarterly*, *74*(4), 426–441. https://doi.org/10.1111/hequ.12244

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, *61*(S1), 631–652. https://doi.org/10.1111/1468-0084.0610s1631

Maneejuk, P., & Yamaka, W. (2021). The impact of higher education on economic growth in ASEAN-5 countries. *Sustainability*, *13*(2), 520. https://doi.org/10.3390/su13020520

Marra, A., & Colantonio, E. (2021). The path to renewable energy consumption in the European Union through drivers and barriers: A panel vector autoregressive approach. *Socio-Economic Planning Sciences*, *76*, 100958. https://doi.org/10.1016/j.seps.2020.100958

McCoskey, S., & Kao, C. (1998). A residual-based test of the null of cointegration in panel data. *Econometric Reviews*, *17*(1), 57–84. https://doi.org/10.1080/07474939808800403

Mehmood, U. (2021). Contribution of renewable energy towards environmental quality: The role of education to achieve sustainable development goals in G11 countries. *Renewable Energy*, *178*, 600–607. https://doi.org/10.1016/j.renene.2021.06.118

Moon, H. R., & Perron, B. (2012). Beyond panel unit root tests: Using multiple testing to determine the nonstationarity properties of individual series in a panel. *Journal of Econometrics*, *169*(1), 29–33. https://doi.org/10.1016/j.jeconom.2012.01.008

Nguyen Dang, H. A., Khan, A., Doan, A. T., & Ibbett, N. (2022). The social impact of green innovation: Towards a conceptual framework. *International Journal of Public Administration*, *45*(5), 399–411. https://doi.org/10.1080/01900692.2021.1913747

Noureen, S., Iqbal, J., & Chishti, M. Z. (2022). Exploring the dynamic effects of shocks in monetary and fiscal policies on the environment of developing economies: Evidence from the CS-ARDL approach. *Environmental science and Pollution Research International*, *29*(30), 45665–45682. https://doi.org/10.1007/s11356-022-19095-0

Nuryakin, N., & Maryati, T. (2022). Do green innovation and green competitive advantage mediate the effect of green marketing orientation on SMEs' green marketing performance? *Cogent Business & Management*, *9*(1), 2065948. https://doi.org/10.1080/23311975.2022.2065948

Pathak, L., & Shah, K. (2019). Renewable energy resources, policies and gaps in BRICS countries and the global impact. *Frontiers in Energy*, *13*(3), 506–521. https://doi.org/10.1007/s11708-018-0601-z

Pedroni, P. (2001). Purchasing power parity tests in co-integrated panels. *Review of Economics and Statistics*, *83*(4), 727–731. https://doi.org/10.1162/003465301753237803

Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory*, *20*(03), 597–625. https://doi.org/10.1017/S0266466604203073

Peng, Z. (2022). Path realization and analysis of synergy between ecological environment development and innovative entrepreneurship education. *Journal of Environmental and Public Health*, *2022*, 8634134. https://doi.org/10.1155/2022/8634134

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265–312. https://doi.org/10.1002/jae.951

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews*, *34*(6–10), 1089–1117. https://doi.org/10.1080/07474938.2014.956623

Pesaran, M. H., & Tosetti, E. (2011). Large panels with common factors and spatial correlation. *Journal of Econometrics*, *161*(2), 182–202. https://doi.org/10.1016/j.jeconom.2010.12.003

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics*, *142*(1), 50–93. https://doi.org/10.1016/j.jeconom.2007.05.010

Pesaran, M. H., & Yamagata, T. (2017). Testing for Alpha in Linear Factor Pricing Models with a Large Number of Securities. CESifo Working Paper, No. 6432, Center for Economic Studies and ifo Institute (CESifo), Munich.

Rasool, H., Maqbool, S., & Tarique, M. (2021). The relationship between tourism and economic growth among BRICS countries: A panel cointegration analysis. *Future Business Journal*, *7*(1), 1–11. https://doi.org/10.1186/s43093-020-00048-3

Salim, R., Yao, Y., & Chen, G. S. (2017). Does human capital matter for energy consumption in China? *Energy Economics*, *67*, 49–59. https://doi.org/10.1016/j.eneco.2017.05.016

Sarwar, S., Streimikiene, D., Waheed, R., & Mighri, Z. (2021). Revisiting the empirical relationship among the main targets of sustainable development: Growth, education, health and carbon emissions. *Sustainable Development*, *29*(2), 419–440. https://doi.org/10.1002/sd.2156

Sharma, R., Sinha, A., & Kautish, P. (2021). Examining the nexus between export diversification and environmental pollution: Evidence from BRICS nations. *Environmental science and Pollution Research International*, *28*(43), 61732–61747. https://doi.org/10.1007/s11356-021-14889-0

Shaturaev, J. (2021). Indonesia: Superior policies and management for better education (Community development through education). Архив научных исследованиЙ, *1*(1), 22–37.

Shoaib, M., Zámečník, R., Abbas, Z., Javed, M., & Rehman, A. U. (2021). Green human resource management and green human capital: A systematic literature review. In Contemporary issues in business, management and economics engineering. *Proceedings of the International Scientific Conference in Vilnius* (pp. 1–10).

Stehlik, T. (2018). International comparisons and case studies. In *Educational Philosophy for 21st Century Teachers* (pp. 203–232). Palgrave Macmillan.

Surkhali, B., & Garbuja, C. K. (2020). Virtual learning during COVID-19 pandemic: Pros and cons. *Journal of Lumbini Medical College*, *8*(1), 154–155.

Swamy, P. A. (1970). Efficient inference in a random coefficient regression model. *Econometrica: Journal of the Econometric Society*, 311–323.

Wang, C., Qiao, C., Ahmed, R. I., & Kirikkaleli, D. (2021). Institutional quality, bank finance and technological innovation: A way forward for fourth industrial revolution in BRICS economies. *Technological Forecasting and Social Change*, *163*, 120427. https://doi.org/10.1016/j.techfore.2020.120427

Westerlund, J. (2005). New simple tests for panel cointegration. *Econometric Reviews*, *24*(3), 297–316. https://doi.org/10.1080/07474930500243019

Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics*, *69*(6), 709–748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

Westerlund, J., & Edgerton, D. L. (2008). A simple test for cointegration in dependent panels with structural breaks. *Oxford Bulletin of Economics and Statistics*, *70*(5), 665–704. https://doi.org/10.1111/j.1468-0084.2008.00513.x

Xing, J., & Fuest, C. (2018). Central-local government fiscal relations and cyclicality of public spending: Evidence from China. *International Tax and Public Finance*, *25*(4), 946–980. https://doi.org/10.1007/s10797-017-9478-8

Yang, S., Liu, W., & Zhang, Z. (2022). The dynamic value of China's high-tech zones: Direct and indirect influence on urban ecological innovation. *Land*, *11*(1), 59. https://doi.org/10.3390/land11010059

Yao, Y., Ivanovski, K., Inekwe, J., & Smyth, R. (2019). Human capital and energy consumption: Evidence from OECD countries. *Energy Economics*, *84*, 104534. https://doi.org/10.1016/j.eneco.2019.104534

Zafar, M. W., Saleem, M. M., Destek, M. A., & Caglar, A. E. (2022). The dynamic linkage between remittances, export diversification, education, renewable energy consumption, economic growth, and CO2 emissions in top remittance-receiving countries. *Sustainable Development*, *30*(1), 165–175. https://doi.org/10.1002/sd.2236

Zahra, S. A. (2021). International entrepreneurship in the post Covid world. *Journal of World Business*, *56*(1), 101143. https://doi.org/10.1016/j.jwb.2020.101143

Zhang, D., Mohsin, M., Rasheed, A. K., Chang, Y., & Taghizadeh-Hesary, F. (2021). The mediating role of green finance is public spending and green economic growth in BRI region. *Energy Policy*, *153*, 112256. https://doi.org/10.1016/j.enpol.2021.112256

Zhang, H. (2021). Technology innovation, economic growth and carbon emissions in the context of carbon neutrality: Evidence from BRICS. *Sustainability*, *13*(20), 11138. https://doi.org/10.3390/su132011138

Zhang, Y., & Dilanchiev, A. (2022). Economic recovery, industrial structure and natural resource utilization efficiency in China: Effect on green economic recovery. *Resources Policy*, *79*, 102958. https://doi.org/10.1016/j.resourpol.2022.102958