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RESEARCH ARTICLE

The role of financial development indicators in sustainable development-environmental degradation nexus

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Abstract

Sustainable development is significantly contributing the environmental degradation due to improvements in financial sector in One Belt and Road Initiative (BRI) region. Thus, the present research work constructs the sustainable development index for BRI. Afterwards, it unfolds the nexus of sustainable development-environmental degradation and also evaluates the role of financial development indicators in BRI economies. By utilizing the robust mean group, the present study quantifies the long-run marginal impacts of sustainable development, financial development indicators, energy consumption, and urban sprawl on environmental degradation, respectively. The marginal impacts infer an inverted U-shaped sustainable development environmental Kuznets curve in BRI region. The sustainable development, energy consumption, and urban sprawl are enriching the environmental degradation, whereas the financial development indicators have an adverse impact on environmental degradation by induction of interaction of sustainable development-financial development. Therefore, the improvements in financial development indicators will help to achieve the sustainable development.

Keywords One Belt and Road Initiative · Financial development · Environmental Kuznets curve · Environmental degradation · Sustainable development · Urban sprawl

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Introduction

The economic and political dynamics of the international system are in flux. Perhaps, the post-cold war era and the global financial crisis (GFC) revamped patriotism and isolationism in global politics (Khan et al. 2018). The recent political progression such as United Kingdom's Brexit and "America First" anti-globalization speech-making of President Donald Trump, corroborates that, in the West nationalism, protectionism and isolation overrun the globalization (Crouch 2017; Ahearn 2006). The western societies have started to recognize that the standard business practices and processes have completely lost traction in response to GFC 9 Sirkin et al. 2008). The aftermath of GFC has driven western powers, particularly, the USA, to protect its domestic industries through erecting tariffs which have resulted in worst international trade in the last 30 years (Rong 2016). Conversely, China's views on the trade openness and commerce persist and utterly contradict the trade and political preferences of the US and the European Union (Hal Brands 2017).

The Chinese President Xi Jinping allocates the endowments to New Silk Road Economic Belt across Eurasia to

connect China with Europe, the Middle East, and South Asia on September 2013 at Kazakhstan (PRC Ministry of Foreign Affairs 2013). Subsequently, Chinese officials have publicized aspiring plans and interest to invest billions of dollars in developing infrastructure in partner countries particularly the highways, pipelines, railroads, and power grids adjacent with ports which shall be upgraded for maritime logistics. The land belt and maritime belt collectively named as One Belt, One Road (OBOR) or Belt and Road Initiative (BRI) (Hafeez et al. 2018). Initially, official reports predicted that China will invest US$800 billion to USS1 trillion which covers 890 projects in more than 60 partner countries (The Economist 2016). BRI is the largest single country initiative in the history of mankind which focuses on enhancing cooperation between Eurasian countries and has the prospective to alter the world trade and integrate regional development. BRI initiative is estimated to impact 2/3 of world population covering 1/3 of global GDP and 1/4 of world trade (Mckinsey 2016; Hafeez et al. 2018). Factually, numerous branches will be built to connect these routes. The complexity and scale of BRI signify that key cities and ports will focus on the development of six major economic corridoes; PRC-Central Asia-West Asia, Bangladesh-PRC-India-Myanmar, PRC-Pakistan, New Eurasia Land bridge, PRC-Indochina Peninsula, and PRC-Mongolia-Russia corridors (PRC The State Council 2015).

It is difficult to evaluate BRI's impact due to the fact that it is driven through a unique blend of strategic and domestic factors. China aims to foster its international trade and foreign economic relations through investment in international transit and logistics. It will not only act as a catalyst in achieving a friendly political acceptance by partner countries but also promote the impact of Chinese-based financial institutions such as "Asian Infrastructure Investment Bank (AIIB) and the BRICS New Development Bank" (PRC Ministry of Foreign Affairs 2015). China aims to stipulate new business opportunities to the domestic companies by diverting overcapacity particularly in cement and steel industry which will help these industries during economic slowdown to act as a regional representative of the Chinese government (Dollar 2015). BRI is considered as an ultimate game changer as the country has never launched such a massive project in the past whose outcomes are projected far-reaching even parallel to the US Marshall Plan (South China Morning Post 2015).

Preliminary studies and the global response to BRI tend to categorize it either as "gamers" (geopolitical implications) or "traders" (anticipated developmental consequences) (Ruseckas 1998). Gamers speculate that BRI through its financial institutions such as AIIB will challenge the Western-led financing system and global governance which will place China at a key position among the international governance bodies. Nonetheless, traders drew attention to the need for investment in infrastructure development in Eurasia and neighboring regions. It was projected that by next decade Asia will require another US$8 trillion to redeem underinvestment and the escalating demand (Tahilyani et al. 2011). Despite traders' contradictory views toward the impacts of BRI, lavish foreign investments are expected to contribute to the humanitarian to political to economic to the regional companies and simultaneously create opportunities for Western investors and financial institutions (Salman et al. 2012). The proceeding argument suggests that it is timely to assess the influx of Chinese-led projects particularly from the financial, sustainable, and environmental context which will incorporate the critical discussion on political agendas, social conditions, and networks across different regions. The actual empirical impact of BRI initiative has largely remained unexplored in the region, as most of the previous studies had adopted a descriptive and conceptual approach to determine BRI impact (Enderwick 2018; Cooley 2016; Khan et al. 2018; Liu 2018). It is considered a significant research gap; hence, the tentative focus of this research is to empirically determine the financial development, sustainable development, and environmental degradation in the BRI region.

Literature review

BRI overview

The ancient Chinese philosophy of "Silk Rood Sprit" underpins the roots of BRI initiative to foster peace and enhance cooperation, openness, inclusiveness, mutual learning, and mutual benefit among all the societies (Xihua 2015). The Chinese officials are zealous in developing six corridors through roads, railways, and sea networks. It is believed that developing transportation infrastructure is a giant leap toward the creation of economic corridors which will provide traction to the landlocked Eurasian economies and strengthen them tightly to China (Rolland 2017).

Initially, US$1 trillion were allocated in 2013 as seed money which proves the strategic significance of BRI for China. Due to the anticipated outcomes and its impact on China, the project was able to attract an additional US$8 trillion to establish infrastructure throughout BRI region, specifically in Asia. Chinese scholars argue that BRI not only focuses on developing infrastructure but also acts as a policy and cultural dialogues among partner countries. It will empower China to establish an image of responsible global power through enhanced financial support, infrastructural connectivity, and trade (Mohieldin 2017).

BRI is a signatory of a continuous dedication by the Chinese government which requires interactive endeavors from the partner countries to maintain inclusive balanced development. The developing countries are in need of investment to establish infrastructure which is an essential component of economic and industrial development (Bei 2017).

Under BRI's umbrella, China will provide 3.5 trillion US$ of financial resources as a foreign exchange reserve along with extensive expertise in the development of infrastructure. Lai et al. (2018), concluded that BRI is a mammoth infrastructural development initiative which promises to contribute to industrial and economic prosperity within region. The projects under BRI involve approximately 70% of the world population, 75% global energy resources, 25% world trade, and 55% global GDP (Lehmacher 2016).

Financial development

China fully understands the negative consequences of anti-globalization and positive outcome of embracing it which is a moral lesson learned from the past. In light of this lesson, China is striving to develop a new form of globalization which is labelled as "Chi-globalization." It is a process guided towards the search for alternative financial routes for the development of societies purely based on contradictory principles of Eurocentric model (Jia 2017). Especially the developing countries such as Pakistan and many others have always relied upon foreign aid to support infrastructure development (Salman and Hui 2009). For infrastructure development of foreign countries, China has established its own economic and political network to influence global governance and contribute to infrastructure development. The new political agenda visualizes the extension of peaceful coexistence, connectivity, and infrastructure development across Eurasia, Europe, central Asia and Africa. China projected that the BRI provides a new global governance model which will help the country to improve its soft image in international politics (Ferdinand 2016),

whereas financial experts and economist have raised their concerns over the financial development in partner countries through BRI (Anderlini et al. 2018; Holslag 2017). A Chinese-based bank AIIB whose size is larger than the World bank will support BRI, and there are serious concerns over the compatibility of Chinese financial institutions to comply with the needs and norms of regional countries. Since this financial institution is the servant of the Chinese government and the governance of investment by this institution is also questionable hence, question is, whether these financial institutions will support infrastructure development or act as a bedrock for political stability? (Davies et al. 2016). BRI is referred as an ambiguous geopolitical plan, an economic bubble and frivolous infrastructural project which will ultimately collapse and will leave economically fragile region indebted to China (Fair 2018). However, China reacted to this verdict and declared it as a political attempt to restrict its economic and political influence in the region (Boriçi 2018).

In addition, financial and economic development in the past had entangled in ethnic tensions and distributional divergences in several countries. The construction of US$3.6 billion Myitsone dam in Myanmar was abolished after the reversal of civilian rule by the parliament. The project was politicized due to the concerns over environmental degradation, anti-Chinese sentiment, and continuing dispute concerning Kachin rebels and local government. An anti-Chinese sentiment was discovered in Pakistan when Baloch rebels attacked Chinese mining and construction projects led due to the conflict between the government of Pakistan and the rebels. A major planned spur of the BRI in Pakistan named as Pak-China Economic Corridor spans through the mountains of Karakorum highway all the way through to the port of Gwadar which is also prone to insurgent attacks (Sha 2016). Many other countries such as Sir Lanka, Kyrgyzstan, and Zambia presidential election candidates were seen campaigning against the legitimacy of Chinese investments and contracts. All these cases obscure that large-scale financial development commitments in BRI are subject to political posturing, nationalist and competitive nationalist appeals (Cooley 2016).

Finance, trade, and investment development in BRI

Financial sector as crucial driver of economic growth triggers the deficits and surpluses of sector an economy (Raheem et al. 2020). Despite the existence of significant shortfall of demand and sluggish economic performance globally, the total volume of trade between China and BRI partner countries was recorded RMB6.3 trillion Yuvan (US$915 billion) in 2016 (Xinhua 2016). China yielded a record of 36% growth and secured a total of US$126 billion through newly signed foreign contracts (MOFCOM 2015). The imports and exports volume of imported goods and services from BRI countries hit the landmark of US$6.53 trillion in 2015, while the exports reached US$7.12 trillion. The total exports and imports from BRI countries made up 33.7% of the total trade volume in the world. Regionally, Southeast Asian countries recorded trade of US$2.3 trillion and Europe US$2.1 trillion and West Asia and North Africa recorded trade of US$1.9 trillion. In terms of overall imports, Southeast Asia was still a leading importer of foreign goods. Among the countries Singapore remained the leading importer and exporter of goods in 2016.

Sustainable development

BRI is characterized as a moral political model enrooted in Chinese Philosophy. The modern-day Chinese leadership acknowledges that the Western political and economic policies have amplified the gap between the North and the South which is a major threat for the global environment. The apparently visible gap nourished through political disputes has promoted inequality, poverty, and human displacement and has enhanced concerns over security and risks to human beings (Ramo 2004). China has

always shown a readiness to take responsibility of global governance to create a peaceful, developed, and harmonious world known as "meihaoshenghuo" in Chinese which means a happy life for everyone. The 2030 Agenda, for example, ever since it was launched, China has pursued national policy arrangements and specified measures for the promotion and implementation of the Agenda which represents China's exceptional role as a global leader in achieving sustainable development goals (SDGs). China released a China's Position Paper in April 2016 which constituted strategic information on the implementation of the 2020 Agenda. Moreover, China established domestic coordination mechanism through 43 government departments to maintain the ingenious progress in implementing the 2030 Agenda (UNDP 2017).

BRI has created an updated framework toward globalization which is based on win-win cooperation. The financial institutions such as AIIB, BRICS, and NSRF offer colossal development opportunities for the partner countries (Sandano 2017). In the light of Chinese philosophy of shared development, a fully functional BRI project will constitute distinctive impacts on sustainable development, whereas Cooley (2016) argued that the regional political dynamics entangle the infrastructure development as many countries have opposed increasing Chinese influence. The Chinese sentiments are largely opposed due to the fact that local communities consider BRI as a method to enhance Chinese political influence rather than create a partnership.

Urban sprawl

According to the 2030 Agenda's SDG-11, urbanization and sustainable development have a concrete link which indicates the significance of developing sustainable cities and communities, secure and resilient human settlements and the cities' commitment in promoting sustainable development. Based on the past experience from the opportunities and challenges of urban sprawl, the 2030 Agenda emphasizes on the need of creating a balanced implementation plan (UNDP and UNRISD 2017). The global South is a house to the world's 24 megacities having a population over 10 million. Most of these megacities are located in the developed regions of China and India (UNDESA 2016). These cities face numerous challenges such as 1.9 billion people located in these megacities are prone to high morality risks from natural disasters (UNDESA 2016). BRI is projected to impose a formative impact on the world economy, society, quality of life, and global consumption of resources and energy. Moreover, BRI is anticipated to contribute to the growing infrastructure needs of the urban population, projected 6.5 billion by 2050 (UNDESA 2016).

Environmental degradation in BRI

The global warming is intensified through environmentally unstable methods which continue to worsen the air quality through the greenhouse gas emission, air pollution, usage of land for energy, electricity, and production. The agriculture, food production, forests, biodiversity, species, water resources, and climate are among the most affected areas. The human activities directly impact on climate change and environmental degradation (IPCC 2015). The UN Environment Programmes (UNEP) issued Emission Gap Report in 2016 and warned that world is warming by 3.0–3.2 °C despite countries that were able to achieve Nationally Determined Contributions (NDCs) pledge during the COP 21 in Paris Agreement in 2015.

BRI is expected to have multidimensional direct or indirect impacts on human endeavors. Arguably, it is expected to pose positive impacts on economies through globalization whereas, and its negative impacts are characterized as environmental degradation through the consumption of higher energy required for electricity generation, transportation, construction of infrastructure, industrialization, urbanization and deforestation for the sake of roads and railway lines (Laurance 2018). China is not only the second largest growing economy of the world but also the leading energy consumer and carbon dioxide (CO2) emitter, and its emission accounts to 30% of global CO2 emission (USEIA 2014).

Of the Chinese, 98.68% (1.34 billions) are living in vulnerable areas due to intensive economic growth, environmental degradation, and population aging (He et al. 2018a). Through CO2 emission, China has become the significant producer of greenhouse gases (GHGs) which release CO2 in the air (Apergis and Ozturk 2015), because China is emitting 28.6% of total world CO2 emission (Li et al. 2019). Consequently, GHGs and water resource consumption are two critical challenges for Chinese economy (He et al. 2018b). Under uncertainty, life cycle is main hurdle in environmental performance regarding the Shale gas supply chain (Chen et al. 2018). There is an evidence of climate aggression effect in Tibet and Arctic (Lu et al. 2020). Thus, authorities and society have to take steps to tackle CO2 emission at initial stage of economic development (Mahmood et al. 2020).

Xu and Lin (2016) concluded that growth in economy and industrialization drives China to emit CO2. Non-renewable energy enhances the CO2 emission (Shaheen et al. 2020). Energy intensity is also an imperative driver of CO2 emission (Lv et al. 2019).

The alarming CO2 level in the air has driven China to discover renewable power technologies to produce energy and create green national economies. Through BRI China has shifted its polluted industrial sector to less developed regions where local authorities are paid to manage the ecological challenge. Global environment institute statistics show that

currently, China is administrating 240 coal-based projects in 25 countries such as India, Indonesia, Magnolia, Vietnam, and Turkey to install a capacity of 251 gigawatts.

Additionally, Chinese firms have planned to establish 92 supplementary projects in 27 economies. China's largest overseas investment emerged on building a coal power station in Pakistan. A precise analysis of the BRI region shows that CO2 emission level in certain economies continues to rise over the last few years which has become an enormous threat to the climate. BRI region shows an inconsistent trend in CO2 emission, while in China itself it has gained consistent rise and reached to 61.4% (BP Statistical Review of World Energy (2017). The proportion of energy intensive emission of CO2 in BRI has reached 80% which indicates the crucial contribution of economies in regional environmental degradation. Based on these facts, it can be asserted that most of BRI projects are not environment friendly. Howard and Howard (2016) found that BRI is a global shifting wave which is projected to influence on indigenous resources and ecosystem. Lastly, China's past record in environmental protection in overseas indicates the lack of commitment in enforcing mechanism and provides one of the many reasons to be concerned about the environmental impact of BRI in the region.

Data and method

Sample set and descriptive analysis

This research work contains a panel of 43 BRI countries from 1991 to 2017. Data availability of under-considered variables is the selection criteria for both countries and time span. It is notable and significant to remark that the present research work has utilized the longest available sample-set to scrutinize the role of financial development and sustainable development in environmental degradation of BRI region. The dataset of all under-considered variables of present study is retrieved from world development indicator (WDI) and also converted into natural logarithm to compute the elasticities of environmental degradation considering the financial development, sustainable development, energy consumption, and urban sprawl (World Development Indicators, 2017). The financial development (FDP) is quantified by domestic credit to financial sector (FS), private sector (PS), and by banks (BS) as percentage of GDP, respectively (Hafeez et al. 2019a; Katircioglu and Taspinar 2017). Total greenhouse gas (TGHG) emissions are taken to measure the environmental degradation (Hafeez et al. 2019a). Energy consumption (ENR) is measured through aggregate energy usage per $1000 GDP (Hafeez et al. 2019b). Urban population (URP) as percent of total population is used as proxy of urban sprawl (Charfeddine and Ben Khediri 2015).

The novel contribution of present research work is to construct the composite index of sustainable development (SUSDP) for BRI. By using the principal component analysis (PCA), the SUSDP is developed through four indicators: per capita GDP at constant 2010 US dollar , Foreign direct investment as percent of GDP (FDI), education (number of pupils in Primary education), and percent of employment to total population. The PCA analysis is demonstrated in Table 1. Equation 1 depicts the computation of SUSDP index.

$$SUSDP = \sum_{i=1}^{4} W_i \times susdp_i \tag{1}$$

In Eq. 1, "i" shows the 4 sub-dimensions; SUSDP1 = per capita GDP, SUSDP2 = FDI, SUSDP3 = education, and SUSDP4 = employment. W_i is the weight of each indicator and calculated as follows:

$$W_i = \left(\frac{v_i}{\sum_{i=1}^{4} v_i} \right) \tag{2}$$

where v_i is the ratio of variation explained by each indicator.

The summary statistics are stated in Table 2. It concludes that energy consumption and urban sprawl are less volatile as compared with environmental degradation, sustainable development, and financial development indicators. Environmental degradation has positively correlated with sustainable development (18.6%), energy consumption (21.6%), and urban sprawl (16.5%), respectively. Sustainable development is positively associated with energy consumption, domestic credit to private sector, and by banks subsequently and negatively associated with urban sprawl and domestic credit to financial sector. Furthermore, urban sprawl and energy consumption have positively and negatively correlated with financial development indicators, respectively.

Econometric design

The core contribution is the development the index of SUSDP, and empirically quantifies the nexus of sustainable development-environmental degradation along the financial development for BRI region. Financial sector is enriching the economic efficiency through financial development (Hafeez et al. 2019a). Energy disparity can be reduced through financial development (Li et al. 2020). It is also an imperative element of economic growth to achieve economic efficiency (Yang et al. 2020). Similarly, Katircioglu et al. (2018) and Katircioglu and Taspinar (2017) suggest that financial development improves the FDI, banking, and financial sector of economy by reducing

Table 1 PCA analysis for SUSDP index

Component (C)	Eigen value	Difference	Proportion	Cumulative
C_1	1.78385	0.745172	0.4460	0.4460
C_2	1.03868	0.162269	0.2597	0.7056
C_3	0.876409	0.575346	0.2191	0.9247
C_4	0.301063	-	0.0753	1.0000
SUSDP indicators	**Variation explained by indicator**			
$SUSDP_1$	0.0327			
$SUSDP_2$	0.7240			
$SUSDP_3$	0.0047			
$SUSDP_4$	0.6890			

C1 to C4 are components of PCA, SUSDP1 = per capita GDP, SUSDP2 = FDI, SUSDP3 = Education, and SUSDP4 = Employment

the spread in risk and financial cost. Hence, it encourages the advance technology usage, triggers the economic process, and brings dynamics in environment (Hafeez et al. 2019a). Consequently, the SUSDP and financial development indicators have taken as input variables for output variable (TGHG). The study of Hafeez et al. (2019b) suggests that energy consumption uplifts the CO2 emission in 12 regions across the globe. Energy disparities upsurge the environmental degradation in BRI regions except the South Asia (Hafeez et al. 2019c). Likewise, the urban sprawl upsurges the infrastructure by development in business and also increases the consumer demand and, hence, environmental degradation (Charfeddine and Ben Khediri 2015; Hafeez et al. 2019a). Thus, the variables ENR and URP as control variables are modelled in estimated models. Equation 3 depicts the econometric specification to quantify the impact of SUSDP, financial developments indicators on TGHG, and also testing the sustainable development environmental Kuznets curve (EKC).

Table 2 Summary statistics

Variables	TGHG	SUSDP	ENR	URP	FS	PS	BS
Correlation							
TGHG	1						
SUSDP	0.186	1					
ENR	0.216	0.111	1				
URP	0.165	−0.227	0.053	1			
FS	0.193	−0.033	−0.194	0.056	1		
PS	0.242	0.091	−0.306	0.271	0.390	1	
BS	0.245	0.091	−0.309	0.276	0.389	0.996	1
Descriptive stats							
Min	2.416	7.821	1.677	0.962	−10.151	0.066	0.066
Max	7.095	41.708	2.841	2	2.332	2.221	2.221
Mean	4.835	27.492	2.166	1.727	1.603	1.487	1.476
Std. Dev.	0.808	5.526	0.221	0.195	0.612	0.374	0.376

$$TGHG_{it} = \gamma_0 + \gamma_{1t} SUSDP_{it} + \gamma_{2t} SUSDP^2{}_{it} + \gamma_{3t} FDP_{it} + \gamma_{4t} ENR_{it} + \gamma_{5t} URP_{it} + \varepsilon_{1it} \quad (3)$$

In Eq. 3, t and "i" represent the time span, i.e., 1991–2017, and number of cross-sections, i.e., 43 BRI countries; TGHG is the environmental degradation; SUSDP and SUSDP2 are the sustainable development and square of sustainable development for EKC hypothesis testing; FDP is the financial development indicators; domestic credit to financial sector (FS), private sector (PS); and by banks (BS), ENR and URP stand for energy consumption and urban sprawl subsequently. The expected signs of $\gamma_1 > 0$, *and* $\gamma_2 < 0$ to validate the inverted U-shape sustainable development EKC hypothesis for BRI region (Hafeez et al. 2018). Energy consumption and urbanization are directly with environment and reveal the marginal impacts of financial development on environmental degradation (Hafeez et al. 2019a, b; Charfeddine and Ben Khediri 2015). Hence, these variables are incorporated to tackle the specification bias problem.

Equations 4 is the extended version of Eq. 3; another input variable, an interaction among SUSDP and FDP indicators, has been modelled as function of TGHG to examine whether improvements in FDP indicators will help to accomplish the sustainable development. Therefore, the sustainable development due to financial development may have positive or adverse impact on environmental degradation.

$$TGHG_{it} = \gamma_0 + \gamma_{1t} SUSDP_{it} + \gamma_{2t} SUSDP^2{}_{it} + \gamma_{3t} (FDP{*}SUSDP)_{it} + \gamma_{4t} ENR_{it} + \gamma_{5t} URP_{it} + \varepsilon_{1it} \quad (4)$$

Estimation scheme

Testing of cross-sectional dependence and unit roots in BRI

This research work contains a sample set of a panel of 43 economies of BRI. So, there are various advantages;

sample variation, unbiased estimates, suitable degree of freedom, and calculate the composite analysis of macro-economics, and advantages; heterogeneity and cross-sectional dependence issues, to analysis the panel dataset by comparing the time series analysis (Rauf et al. 2018; Dogan and Seker 2016). To overcome the aforementioned disadvantages, the degree of cross-sectional dependence (CD) is measured by CD tests (Pesaran 2007). Based on Lagrange Multiplier (LM) test (Eq.6), this test computes the level of CD and depends upon the pairwise correlation with respect to square and stated in Equation 5.

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \widehat{\rho}_{ij} \right) \backsim N(0,1) \tag{5}$$

$$LM = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \widehat{\rho}_{ij} \right) \frac{(T-k)\widehat{\rho}_{ij}^{\,2} - E(t-k)\widehat{\rho}_{ij}^{\,2}}{Var(T-k)\widehat{\rho}_{ij}^{\,2}} \tag{6}$$

Afterwards, the present research has considered various macro-economic series to examine the order of integration of sample set and patterns whether it traces the transitory or permanent. Evoking the CD problem in panel data analysis, the first-generation unit root tests for panel data are not able to tackle the CD issues and cannot provide robust and reliable estimates (Liu et al. 2018). To address the CD and heterogeneity issues, the CADF (cross-sectionally augmented Dickey-Fuller) test is considered to assess the order of integration (Liu et al. 2018; Pesaran 2007). The CIPS is also applied to validate the results from CADF test because it calculates the critical value based on cross-sectional average of CADF. The econometric form of CADF is stated in term of TGHG in Eq. 7.

$$\Delta TGHG_{i,t} = \delta_i + \beta_i TGHG_{i,t-1} + \rho_i T + \sum_{i=1}^{n} \theta_{ij} \Delta TGHG_{i,t-j} + \varepsilon_{i,t} \tag{7}$$

Westerlund co-integration test

The first-generation co-integration tests, Johansen, Kao, and Pedroni, are able to incorporate the CD issue. Therefore, the present research work has applied the Westerlund co-integration test to investigate whether long-run relationship with under-considered models exit or not (Westerlund 2007). Based on panel and group statistics, it tests the null hypothesis: no co-integration in all cross-sections and can be elaborated its procedure in Eq. 8 (Westerlund 2007).

$$\Delta TGHG_{i,t} = \delta_i d_t + \delta_i \left(TGHG_{i,t-1} - \beta_i X_{i,t-1} \right) + \sum_{j=1}^{\rho_i} \delta_{ij} \Delta_{i,t-j} + \sum_{-q_i}^{\rho_i} \gamma_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \tag{8}$$

Panel long-run marginal impact

The traditional long-run estimators, generalized method of moments, fixed, and random effects, are not appropriate and cannot address the issues of CD and heterogeneity and estimate the inconsistent marginal impact (Pesaran and Smith 1995). Pesaran and Smith (1995) proposed mean group (MG) approach to estimate average population long-run marginal impact by allowing various cross-sections having the different slopes, intercept, and variances of error, respectively. The MG estimator comes from arithmetic mean of estimated independent model of each cross-section in considered panel (Ozcan and Apergis 2017; Pesaran and Smith 1995). It also computes the consistent estimates in case of time series extended (Ozcan and Apergis 2017). Hence, the present research work adopts the MG approach to compute the long-run marginal impacts (Kao and Chiang 2000). Equation 9 explains the procedure of MG approach.

$$\Delta TGHG_{i,t} = \sum_{j=1}^{p} \theta_{ij} TGHG_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} X_{i,t-j} + \eta_i + \tau_t + \epsilon_{it} \tag{9}$$

In Eq. 9, TGHG is the predicted variable, Xi is the set of the predictor variables that contains sustainable development, and its square, financial development indicators, energy consumption, and urban sprawl, while ϵ_{it} is the error term. η_i *and* τ_t indicate the invariant-time effect for cross-section and time period, respectively. Eq. 10 is resultant of addition of the lag period of TGHG t-1 in both sides of Eq. 9.

$$TGHG_{i,t} = \sum_{j=1}^{p} \omega_{ij} TGHG_{i,t-j} + \sum_{j=0}^{q} \beta_{ij} X_{i,t-j} + \eta_i + \tau_t + \epsilon_{it} \tag{10}$$

where $\omega_{ij} = \theta_{ij} \; \forall_j \neq 1, \quad \omega_{i,\,1} = \theta_{i,\,1} + 1$

$$\Delta TGHG_{i,t} = \varphi_i \left[TGHG_{i,t-1} - \theta X_{i,t} \right] + \sum_{j=1}^{p-1} \omega_{ij} \Delta TGHG_{i,t-j} + \sum_{j=0}^{q-1} \beta_{ij} \Delta X_{i,t-j} + \eta_i + \tau_t + \epsilon_{it} \tag{11}$$

Equation 11 depicts the error correction of Eq. 10 and can compute individually for each cross-section then provide an average magnitude from all individually estimated cross-sections (Ozcan and Apergis 2017; Pesaran and Smith 1995). For example, the speed of adjustment of MG estimator

suggested by Pesaran and Smith (1995) can be stated as $\widehat{\pi}^{MG} = N^{-1} \sum_{i=1}^{N} \widehat{\pi}_i$ with the variance $\widehat{\Delta_{\widehat{\pi}}} MG = \frac{1}{N(N-1)} \sum_{i=1}^{N} (\widehat{\pi}_i - \widehat{\pi})^2$.

To check the stability and robustness of estimates, this research work also applied FMOLS approach which also addresses the heterogeneity and cross-sectional dependence issues in panel data analysis (Kao and Chiang 2000).

Empirical results and discussions

In recent decades, the both developing and developed nations have interdependence among them due to spill-over effects of spatial and cross-boarders (Pedroni 2004; Hafeez et al. 2019b). Likewise, the study of Liu et al. (2018) recommends the CD test as preliminary test of cross-sectional dependence to move towards the unit root analysis. To do this, the CD tests are utilized and reported in Table 3. The results from CD tests infer that OBOR countries are cross-sectionally dependent. Thus, the conventional panel unit root tests are not appropriate to investigate the order of integration (Hafeez et al. 2019b). To address the CD and heterogeneity issues, Pesaran (2004, 2007) has recommended the second-generation unit root tests, CADF and CIPS, to check the integration order and presented in Table 4. The outcome of both unit root tests infer that all under-considered variables are stationary at level. Table 5 depicts the results from Westerlund (2007) and infers the existence of long-run relationship among under-considered variables in FS, BS, and PS model, respectively.

The MG method reveals the valuable insights, and computes the long-run marginal impact of sustainable development, financial development indicators, energy consumption, and urban sprawl on environmental degradation for BRI, as reported in Table 6. The empirical estimates deduce the inverted U-shape EKC of sustainable development in BRI along all financial development indicators. Sustainable development is significantly enriching the environmental degradation in FS, BS, and PS model, respectively (2nd , 4th and 6th columns of Table 6). China has always shown a readiness to take responsibility of global governance to create a peaceful, developed and harmonious world (Xi, 2017). The expansion of major sectors of an economy triggers the economic activities which enriches the carbon footprints (Ahmed et al., 2019). As the Sustainable Development goals (SDGs) 2030 vision is to attain growth in digital economy, regional financial, and trade (Hafeez et al. 2019a), it implies that an increase of 1% in sustainable development upsurges the 0.095, 0.082, and 0.076% in environmental degradation with respect to financial development of financial, private, and bank sector, respectively.

The energy consumption and urban sprawl boost the environmental degradation in BRI region in estimated models (2nd , 4th and 6th columns of Table 6) which is similar to results of studies of Hafeez et al. (2019b), Yasmeen et al. (2018), and Liu et al. (2018), respectively. The study of Hafeez et al. (2019a) recommends that financial sector improvements allow investors to develop the business by getting easy loans and, hence, arise in energy consumption. Energy disparities are initiating the environmental degradation in BRI regions (Hafeez et al. 2019c). Similarly, the carbon footprints trace the uprising trend in BRI due to expansion in energy consumption (Hafeez et al. 2019a). Urban sprawl is increasing the CO2 emission in East Asia and Middle East, respectively (Liu et al. 2018).

The financial development indicators have positive but significant impact on environmental degradation (2nd , 4th and 6th columns of Table 6). The financial development provides

Table 3 Results of cross sectional independence tests

Variables	TGHG	SUSDP	ENR	URP	FS	PS	BS
CD-stats	118.96	114.66	103.72	119.99	69.14	89.45	90.28
Prob.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residuals cross sectional independence							
	Frees' test		Pesaran CD test		Friedman's test		
	22.259		113.211		1045.853		
Prob.	0.00		0.00		0.00		

Table 4 panel unit root tests

Variable	CADF (C)	CADF (T)	CIPS (C)	CIPS (T)
TGHG	−4.207*	−4.16*	−5.803*	−6.030*
SUSDP	−4.567*	−4.912*	−6.129*	−6.331*
ENR	−4.885*	−4.938*	−6.107*	−6.322*
URP	−4.438*	−4.65*	−5.906*	−6.002*
FS	−5.117*	−5.196*	−6.147*	−6.368*
PS	−4.336*	−4.458*	−6.126*	−6.339*
BS	−4.409*	−4.525*	−6.132*	−6.337*

(C) , and (T) mean constant, and Trend. While , * shows the 1 % level of significance

Table 5 results of Westerlund (2007) co-integration test

Westerlund cointegration test				
Stats	G_t	G_a	P_a	P_t
FS Model	−3.664*	−19.708*	−18.413*	−22.944*
PS Model	−3.238*	−19.900*	−16.927*	−21.106*
BS Model	−3.198*	−19.921*	−16.731*	−20.880*

Note: * shows 1% level of significance

Table 6 MG estimates

Variables	FS Model		BS Model		PS Model	
	Marginal impact	Pro.	Marginal impact	Pro.	Marginal impact	Pro.
EKC Hypothesis						
SUSDP	0.095*	0.00	0.082*	0.00	0.076*	0.00
$(SUSDP)^2$	−0.001*	0.001	−0.001*	0.00	−0.0009*	0.00
ENR	1.045*	0.00	1.040*	0.00	1.022*	0.00
URP	0.606*	0.00	0.435*	0.00	0.454	0.00
FS	0.807*	0.00	-	-	-	-
BS	-	-	0.703*	0.00	-	-
PS	-	-	-	-	0.6971*	0.00
Constant	−1.488*	0.00	−0.625*	0.00	−0.5442*	0.00
Wald Chi ^{2}	1876.43	0.00	2129	0.00	2066.77	0.00
EKC Hypothesis + interaction Models						
SUSDP	0.0026	0.881	0.0181	0.296	0.0014	0.933
$(SUSDP)^2$	−0.0011*	0.003	−0.0009*	0.000	−0.0008*	0.000
ENR	0.9778*	0.000	1.0013*	0.000	0.9837*	0.000
URP	0.6589*	0.000	0.4917*	0.000	0.5206*	0.000
FS	−0.640*	0.007	-	-	-	-
BS	-	-	−0.3596	0.118	-	-
PS	-	-	-	-	−0.547**	0.020
FS* SUSDP	0.0523*	0.000	-	-	-	-
BS* SUSDP	-		0.03674*	0.000	-	-
PS* SUSDP	-	-	-	-	0.04281*	0.000
Constant	1.116*	0.005	1.124**	0.011	1.5009*	0.001
Wald Chi ^{2}	1134.07	0.00	2507.17	0.00	2492.32	0.00

*,**, and show the 1 , 5, and 10 % level of significance, respectively

the luxuries goods (air conditions, refrigerators, and machinery) to customer which enriches the energy consumption and, hence, environmental degradation (Hafeez et al. 2019c). Secondly, it also enhances the economic activities which yield the environmental degradation (Hafeez et al. 2018). It indicates that an increase of 1% in FS, BS, and PS model (2nd , 4th and 6th columns of Table 6) increases the 0.807, 0.703, and 0697% in environmental degradation.

The present research work is also contributing the existing literature by introducing the interaction term between SUSDP and FDP indicators (SUSDP*FDP) to examine whether improvements in FDP indicators will help to accomplish the sustainable development. The interaction of sustainable development and financial development indicators reveals that financial development is deteriorating the environmental degradation (Interaction Models in Table 6). A healthier environment can be achieved through green investment projects and eco-friendly. The SUSDP*FDP (interaction-term) has a statistically positive marginal impact on environmental degradation in all estimated models (Interaction Models in Table 6).

The aforementioned noteworthy findings may be helpful to devise policy matrix concerning the sustainable development and financial development indicators along with energy consumption and urban sprawl. The focus on efficient usage of energy, and eco-friendly projects, will play a crucial role to enhancing the economic activities along with a controlled the air pollutions. For sensitivity analysis, another panel data estimation approach (FMOLS) has been applied. As Pesaran (2007) and Hafeez et al. (2018) suggest that FMOLS is an appropriate estimator to handle the endogeneity and cross-sectional dependence, the results from FMOLS are reported in Table 7. The estimates from FMOLS validate the estimated results of MG approach (2nd, 4th, and 6th columns of Table 7). Therefore, the estimates of present research work are robust and consistent to devise policies for OBOR region.

Conclusion and policy implications

This study analysis is an effort to explore the nexus of sustainable development and environmental degradation by developing the sustainable development index in selected 43 BRI countries. The standard MG approach is employed to estimate the long-run marginal impact by tackling the heterogeneity and cross-sectional dependence issues (Kao and Chiang 2000). The estimates from MG approach are validated

Table 7 Results from FMOLS

Variables	FS Model		BS Model		PS Model	
	Marginal impact	Pro.	Marginal impact	Pro.	Marginal impact	Pro.
EKC Hypothesis						
SUSDP	0.0521*	0.00	0.0571*	0.00	0.0556*	0.00
$(SUSDP)^2$	−0.0004*	0.00	−0.0006*	0.00	−0.0006*	0.00
ENR	0.8589*	0.00	1.013*	0.00	1.007*	0.00
URP	0.7862*	0.00	0.3769*	0.00	0.3969	0.00
FS	0.3114*	0.00	-	-	-	-
BS	-	-	0.6377*	0.00	-	-
PS	-	-	-	-	0.6297*	0.00
EKC hypothesis + interaction models						
SUSDP	0.0309	0.3351	−0.0395*	0.00	−0.0418	0.145
$(SUSDP)^2$	−5.70E-05	0.9430	0.0005*	0.002	−0.53***	0.083
ENR	0.8375*	0.000	0.2607*	0.000	0.2672*	0.000
URP	0.9210*	0.000	0.4272*	0.000	0.4630*	0.002
FS	0.3251	0.3805	-	-	-	-
BS	-	-	−0.1755**	0.023	-	-
PS	-	-	-	-	−0.2474**	0.022
FS* SUSDP	0.002*	0.0012	-	-	-	-
BS* SUSDP	-		0.01077*	0.000	-	-
PS* SUSDP	-	-	-	-	0.0133*	0.000

*,**, and show the 1 , 5, and 10 % level of significance, respectively

through the FMOLS. The empirical findings infer an inverted U-shape sustainable development EKC in case of BRI countries. The estimated marginal impacts also reveal that an increase in sustainable development will enrich the environmental degradation. Moreover, the financial development indicators, energy consumption, and urban sprawl also uplift the environmental degradation in BRI countries, respectively. However, the introduction of SUSDP*FDP (interaction-term) reveals that the financial development indicators have an adverse impact on environmental degradation. A healthier environment can be achieved through green investment projects and eco-friendly. It concludes that financial development indicators can be helpful to control the environment quality along sustainable development.

The present research work suggests few possible policy proposals in light of estimated results. First, policy-makers may provide easy credit and loans to investors to encourage the green financing. Secondly, carbon tax may introduce to decrease the usage of old technologies and production methods. Third, introduction of eco-friendly and energy-efficient machines will be helpful to optimal usage of energy consumption. Lastly, policy-makers may consider a well-organized urbanization for better environment quality.

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Data Availability The datasets/materials used and/or analyzed for present manuscript are available from the corresponding author on reasonable request.

Compliance with ethical standards

Ethical approval Not applicable

Consent to participate I am free to contract any of the people involved in the research to seek further clarification and information.

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