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Public spending and green economic growth in BRI region: Mediating role of green finance

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ABSTRACT

Generally, public spending on education, research, and development (R&D) is perceived to impact the economy and sustainability positively; however, such notion lacks evidence, particularly in Belt and Road Initiative (BRI) member countries. In this study, panel data of BRI member countries from 2008 to 2018 is analysed using the generalized method of moments (GMM) method and data envelopement analysis (DEA) to assess the relationship between public spending on R&D and green economic growth and energy efficiency. The study found a fluctuating green economic growth indicator during the research period attributed to the non-serious nature of government policies. The findings reveal that the GMM method confirms both composition and technique effects in the entire sample. Nonetheless, the result of the sub-sample showed a heterogeneous effect on high GDP per capita countries. Moreover, the study shows that public spending on human resources and R&D of green energy technologies prompts a sustainable green economy through labour and technology-oriented production activities and different effects in different countries.

1. Introduction

Policymakers worldwide strive to produce sustainable solutions for environmental degradation and uncontrolled climate change (Huntington, 2015). Although for a less polluting economic growth, the government's spending on R&D is considered a significant driver, technology stands as the preferable option to bring about green economic growth. This notion encourages innovation and is promoted by most economic experts. It is eminent to analyse the determinants of a green economy before its implementation. One of the critical indicators of green growth is public expenditure change (Aly et al., 2017). Existing literature indicates that the composition of public spending is directly affected by economic and environmental degradation. The relationship between public spending and green economic growth still lacks considerable evidence (Lepitzki and Axsen, 2018), (Iqbal et al., 2020). Several previous studies support the role of restructuring fiscal expenditures as an essential factor in the growth of the green economy (Facchini and Seghezza, 2018). Although economic growth is accelerated by increased public expenditure, it also decreases green economic progress by augmenting environmental hazards. The theories for neoclassical economics and evolutionary economics explain the recent increase in public spending on environmentally friendly energy solutions to compensate for sub-optimal investment. Market failures can be compensated by public funds, which gives rise to new technological solutions. Private R&D expenditure is not enough to produce groundbreaking solutions; therefore, public financial support is required (Wu et al., 2021). On the other hand, in light of the evolutionary economics theory, the foundation for developing adequate technologies by enterprises cannot be automatically established merely based on the availability of new technologies developed by public expenditures. This means that private sectors need to be involved in this process with the public sector support.

Several economies face a fiscal crisis as governments cannot establish a deficit between public expenditure and taxation. The budget-cuts on a

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green economy make a society miserable due to the consequences of such a crisis (Afonso and Furceri, 2010). The scale of public expenditure in a green economy and the relationship between public expenditure composition and economic growth impact fiscal policy implementation. Some public expenditure components with more significant influence on green economic activity than others give rise to this question. Changing the level and composition of the total public expenditure on R&D enables a country to improve its economic performance (Iram et al., 2020).

The Belt and Road initiative (BRI) by China encourages the construction of large markets through mutual cooperation centric to energy and infrastructure (Sun et al. 2020a, 2020b). Developing countries, particularly in Asia and Africa, see this as a tremendous opportunity due to Chinese banks' lucrative financing offers. While most of the projects are predominantly executed by China, the member countries often have the opportunity to negotiate terms. The strategy of growth amongst the developing economies is shifting from agriculture to modern industrial manufacturing. Developing countries from Asia and Africa are trying to achieve a significant output to support their growth targets by focusing on their industrial sectors (Yang, 2017). Targeting much smooth and enhanced output, emerging countries among BRI members have increased their reliance on energy resources. However, to mitigate global warming, the member countries must cooperate towards green development, in addition to economic interests. Although the various authors proposed studies (Dai et al., 2015) and (Ã and Spreng, 2007) regarding environmental issues in the BRI region, the research is still in its initial phase. Due to the reliance on the industrial sector and non-renewable energy (NRE) resources, green economic growth has improved; however, the continuous degradation of the environment threatens the future (Montalbano and Nenci, 2019) and (Mohsin et al., 2018). According to the literature, the BRI member countries' economic growth can be significantly improved with the BRI project's help. The growth targets can be achieved through energy and living standards (Omri, 2013 and Shah et al., 2019). Specific pointers play a role in the failure of green economic growth, such as too much reliance on NRE, inappropriate environmental planning, and insufficient public spending in the field of research and development (R&D) (Al-mulali, 2011; Acheampong, 2018). With the popular direction distance approach, this study establishes a "green economic growth index" (Lin and Zhu, 2019). Fluctuations in the economy's progress, resource base, and environment scenario are considered in the index construction process. The fluctuations are keenly observed in this index throughout the study. The investigation follows the index's formation to measure the impact of education and R&D expenditure on green economic growth through the two-step system, called the GMM method, used to run econometric estimation. A positive statistical impact is noticed along with the composition effect and the technical effect. The composition effect is recorded to have a more significant impact than the technical effect throughout the observation (Peña-Martel et al., 2018). The impact of the influential prospective channels of public spending on green economic growth is also assessed in this study. According to the results, human capital-based industries can be improved by public spending on the education sector. Similarly, technology advancement can be accelerated by public spending on Research and Development (Xing and Fuest, 2018) and (Martínez-Moya et al., 2019).

This study plays its role in providing instrumental insights for literature. This study's result can support the role of public spending in affecting the green economy movement. Regardless of a consistent study proving this concept, The market mechanism is influenced by government spending. This study proposes the minimised market failure through increased public spending with empirical evidence regarding the presence of composition and technique effect. In this study, green economic growth is recorded to positively correlate with an increase in fiscal spending. Data envelopement has been used to measure energy efficiency for selected countries. The public policy measures broadly impact energy conservation, economic growth, and environmental safety initiatives, and these three variables must have an excellent right balance in the green economy movement. According to this study, governments can foster green economic development by increasing spending on public properties, concluding with some suggestions for the BRI countries to achieve sustainable economic development. The heterogeneity of the sample countries is evident in this study. Hence, in order for different countries to benefit from public spending for green economic growth (green public finance), it is vital to form different development initiatives.

The remaining sections of the study are stated as: Section 2 presents detailed literature on green economics, section 3 introduces the data and methodology, section 4 presents an analysis on the empirical study, section 5 is based on the conclusion and policy recommendations.

2. The green economy: role of clean energy

The global sustainable development for energy and the environment relatively depends on BRI construction (Zhang and Zhang, 2018). With one-third of the global GDP in energy, an estimated 62% of the global population, 39% of the global land area, 24% of household consumption, and approximately half of the world's total energy consumption is based on the countries along the "Belt and Road" (IEA, 2016; see Fig. 1 for the map of BRI). Therefore, the total energy intensity or the energy input per unit GDP is higher for this region, reflecting countries' potential along the "Belt and Road" for cleaning through the production process (Qi et al., 2019). The improvement of the basic connectivity of trade and investment between the Silk Road land and Silk Road sea routes is one of the primary objectives for the "Belt and Road" construction. It is also essential for the countries along the "Belt and Road" to decrease heat consumption through government spending on research and development to achieve economic growth. Demand for high-quality investment in the energy sector is supported by the lack of energy infrastructure, which is one of the main hurdles in achieving sustainable economic development in the countries along with the "Belt and Road," most of which are emerging economies and developing countries (Liu et al., 2020).

It is easy to define a green economy as resource-efficient, low-carbon (clean), and socially inclusive. In a green economy, the growth of employment and income is driven by public and private investment. Such green investments propel economic activities, including green energy infrastructure development to reduce carbon emissions, improve energy and resource efficiency, and protect biodiversity and ecosystems (Sun et al. 2020a, 2020b). As a result, green economic growth has gained attention as a new form of economic mechanism worldwide (Rodriguez-Gonzalez et al., 2018). A precise definition of the green economy is evident in previous studies (Anser, 2019) and (Tehreem et al., 2020). A green economy is termed as a strategic concept responsible for analysing the concept and meaning of "green growth", according to some international agencies' claims, such as the UNEP (2011). The relationship between sustainable development, green economy and green economy's dimensional characteristics with bibliometric analysis is studied in Nieto et al. (2018). Public finance is not enough to achieve green development goals and the Sustainable Development Goals (SDGs) set by The United Nations, according to Yoshino et al. (2020) and Taghizadeh-Hesary and Yoshino (2019). Therefore, the government needs to allow green infrastructural projects to bring more private green finance and investments (Zhang et a. 2019; Taghizadeh-Hesary and Yoshino, 2020).

Green economy and growth are discussed in the literature in great detail. By adopting a green economy, we can produce low carbon discharge and preserve green resources (Lin and Jia 2018). According to some studies, environmental safety and employment generation can help green growth in ensuring economic development. (Iqbal et al., 2020). Wang et al. (2019) applied the input-output measure of energy to study the prospective direction for Canada's green economy under various phenomena. The growth efficiency of green economies of Chinese cities is studied by Zhao et al. (2017). The extent of green economic development in Chinese cities considering various resources is assessed

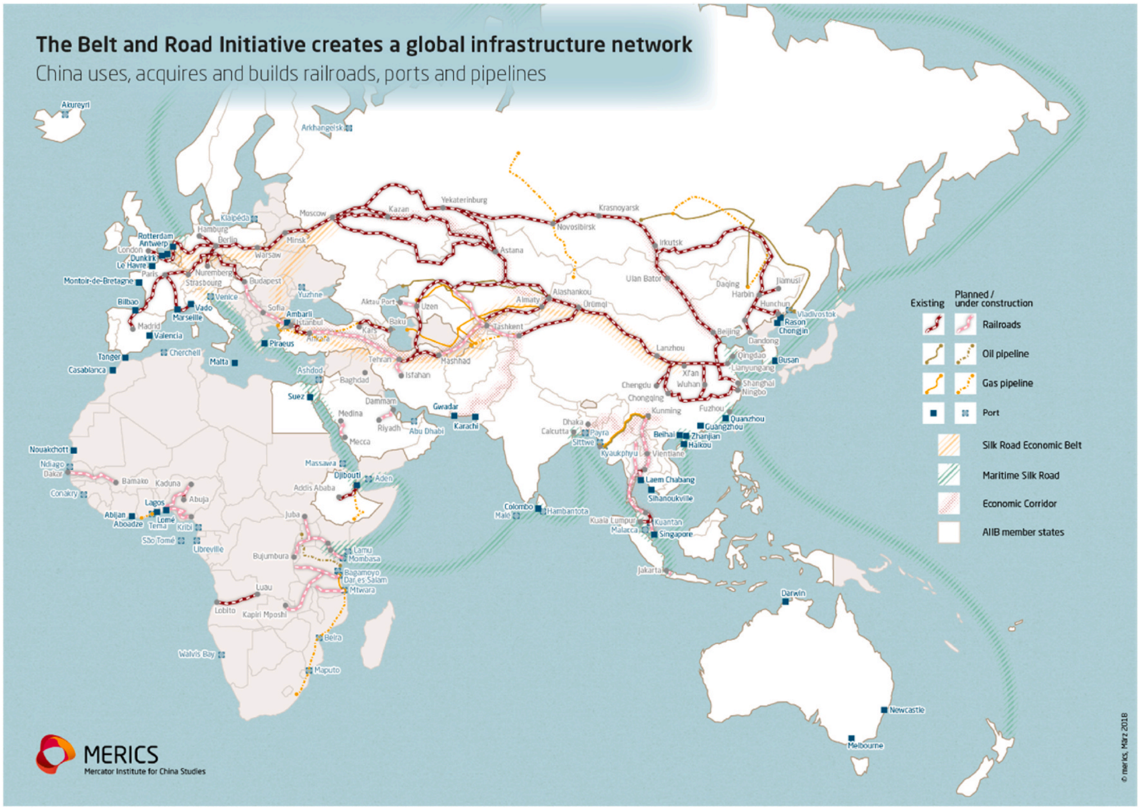

Fig. 1. Belt and Road initiative member countries map (MERICS, 2018).

by Ji et al. (2017). Various other determinants with an influence on green development are studied by many previous works of literature, such as Wang et al. (2019), who based his research on the population, level of education, social and economic status to analyse the variation in the green economic growth of the Chinese cities. Lin and Zhu (2019) assessed the Chinese provinces, introduced an indicator for green economy's growth and applied the quantile formula to assess how green development in the Chinese provinces is affected by the technological shortage, lack of best practice, and efficiency. Shu et al. (2016) concluded how the more resourceful cities have a bigger chance of producing a polluted environment by considering natural and green resources to influence green development growth in China (Liu and Xiao, 2018).

Consequently, a reduction can be observed in the output of poor environmental conditions and the total energy input per unit of the countries' GDP along the "Belt and Road". An increased connection between countries' trade and infrastructure networks along the Belt and Road can also be observed after joint construction of the "Belt and Road" initiative. Therefore, the energy intensity of countries along the "Belt and Road" is encouraged to catch up due to the trade scale effect and the government's investment in the R&D effect. This process plays a crucial role in promoting the green economic growth of trading countries as well as accelerating energy efficiency on the whole (Zhang et al., 2020; Mohsin et al., 2021).

Paramesh et al. (2018) simultaneously assessed the Asian countries for their evolution towards a green economic phase caused by fiscal instruments, which explained how Asian countries materialise the green economic transition at a slow pace. In order to achieve the green economic objective, a country-specific determination of fiscal tools is suggested. Many studies, conducted on the nexus of public expenditure and environmental pollution reduction are evident from the present literature. The academia is yet to assess if a nexus with green economic development and growth in the BRI countries exists for public spending. This study is an attempt to fill the gap through empirical research.

3. Data and methodology

Data from the BRI member countries between 2008 and 2018 is used in the study because of its availability and robustness. The BRI region databases, World development indicator (WDI), official databases of BRI countries' government agencies, BRI countries' environmental regulation (BRIGC & MEE/FECO), and World Bank carbon pricing database; are the source of data.

3.1. Data envelopment analysis approach and green economic indicator

The Slack-Based Method (SBM) is a data-driven method that weights multi-dimensional indicators objectively. It is not eminent to have the specific form of the production function to carry out performance evaluation (Kuang et al., 2020). provides performance improvement direction in addition to performance evaluation (Mahmoudabadi and Emrouznejad, 2019). established the best tool for measuring slacks and validated it as the primary cause of inefficient utilisation of inputs.

For instance, in a production process with both desirable outputs and undesirable outputs being mutually produced, let us consider $\mathbf{X} \in \mathbf{R}_{+}^{\mathbf{N}}$, $\mathbf{Y} \in \mathbf{R}_{+}^{\mathbf{M}}$, and $\mathbf{U} \in \mathbf{R}_{+}^{\mathbf{J}}$ as vectors of underlying inputs, desirable outputs, and undesirable outputs, respectively. We can explain the production technology as,

$$\mathrm{T} = \{(X, Y, U) : X \ can \ produce(Y, U)\} \in \mathrm{R}_{+}^{\mathrm{J}} \tag{1}$$

According to the production theory, T is mostly considered the bounded and closed set, confirming the output closeness. It also suggests a finite quantity of outputs as a result of finite quantity of inputs. In T, the desirable outputs and inputs are considered freely or strongly disposable (Zhou et al., 2006). In that case, if $T = (X, Y, U) \in T \ and \ X^{'} \in X(or \ Y^{'} \in Y)$, then (x′, y, u) ∈T (or (x, y′, u) ∈T). The two following assumptions anticipated by (Färe et al., 1989) are imposed on T to practically model a production technology, producing both desirable and undesirable outputs simultaneously. (i) if (x, y, u) ∈T and 0 ≤ θ ≤ 1, then (x, θy, θu) ∈T as the outputs are weakly disposable. (ii) if (x, y, u) ∈T and u = 0, then y = 0, representing a mathematical form of both the undesirable and desirable outputs as a null joint.

According to assumption (i), it is not free to cause a decrease in the undesirable outputs, while an equal decrease in the desirable and undesirable outputs can be done, considering both desirable and undesirable outputs as weakly disposable. According to assumption (ii) it is compulsory to produce undesirable outputs as desirable outputs are being produced. The subsequent output set is given below also explains this process,

$$\mathrm{P(X)} = \{(Y, U) : (X, Y, U)\} \in \mathrm{T} \tag{2}$$

With x as the vector of the outputs, P(x) represents all the technically feasible outputs. The transitional dealings z is built with the help of x as the primary key vector. The concluding productivity vector y is built by the transitional goods, considering critical vectors of the successive point. The impact, on the whole, can get affected by deficiency in the middle trial (Ringler et al., 2017) and (van de Ven and Fouquet, 2017). For each individual DMU in the objective function of the model (2), the current DEA model considers the light of rare casual conditions as it evaluates the energy efficiency. In contrast, the related but un-identical attributes are explained by the restrictions in models 1 and 2. (x, y, u) ∈T⇔(y, u)∈P(x) can get verified. Considering T, the undesirable outputs' vigorous disposability stands invalid, whereas P(x) can be considered an environmental output set, even though the production technology T has been conceptually well defined, which cannot be directly applied in practical usage. The SBM DEA model is deployed to identify the main events for the DMUs after considering Energy efficiency issue as the much used and monotonous model. A restricting scenario for the central processes is offered by employing the best standards in SBM (Salim and Rafiq, 2012).

A simplification of the traditional single output production functions can be represented by the relationship between the Shephard distance function and T (the directional distance function). Considering their parametric or nonparametric conditions, it is then easy to measure the application of distance functions (Chapple et al., 2005) and (Guo and Zhu, 2017) (Zhou et al., 2006). established the data observed on the vectors of inputs, desirable outputs as follows, considering k = 1, 2, …, K DMUs and for DMUk:

$$X_k = (X_{1k}, X_{2k}, \ldots, X_{Nk}),\ Y_k = (X_{1k}, X_{2k}, \ldots, X_{Mk}),$$

$$u_k = (u_{1k}, u_{2k}, \ldots, u_{jk}),\ \sum_{j=1}^{J} u_{jk} \geq 0\ k = (1, 2, \ldots, K)$$

$$\text{And } \sum_{k=1}^{K} u_{jk} \geq 0\ j = (1, 2, \ldots, J)$$

$$\mathrm{T} = \left\{ (X, Y, U) \sum_{k=1}^{K} z_k x_{nk} \leq \mathrm{x}_n, \quad n = 1, 2, \ldots, N \right. \tag{3}$$

$$\sum_{k=1}^{K} z_k y_{mk} \leq \mathrm{y}_n, \quad m = 1, 2, \ldots, M$$

$$\sum_{k=1}^{K} z_k u_{mk} = \mathrm{u}_j, \quad j = 1, 2, \ldots, J$$

$$\mathrm{z_k} \geq 0, \quad \mathrm{k} = 1, 2, \ldots,\ \mathrm{K}\}$$

The environmental DEA technology characterised by the output set is bounded and closed. With the subscript "0″, signifying an assessed DMU in the existing literature (Tyteca, 1996). emphasises that the undesirable outputs oriented DEA model is preferred. With a value greater than 0 and less than 1, the standardised and aggregated energy efficiency is provided to assess the environmental performance (Zaim, 2004).

$$EI = \lambda^* = min\lambda^* \tag{4}$$

$$\text{s.t} \sum_{k=1}^{K} z_k x_{nk} \leq \mathrm{x}_{n0}, \quad n = 1, 2, \ldots, N$$

$$\sum_{k=1}^{K} z_k y_{mk} \geq \mathrm{y}_{m0}, \quad m = 1, 2, \ldots, M$$

$$\sum_{k=1}^{K} z_k u_{jk} = \lambda^* \mathrm{u}_{j0}, \quad j = 1, 2, \ldots, J$$

$$\mathrm{z_k} \geq 0, \quad \mathrm{k} = 1, 2, \ldots,\ \mathrm{K}\}$$

Regardless of applicability, the inputs and desirable outputs of the slacks are not included in the model. Due to this process, the energy efficiency of two DMUs can have the same value of 1, even if one of the DMUs has a better set of inputs and desirable outputs than the other. A framework is developed to remove this shortcoming (Cooper et al., 2007) and (Tone, 2001)

$$\rho^* = \min \frac{1 - \frac{1}{N}\sum_{n=1}^{N} s_n^- / s_{n0}}{1 + \frac{1}{M}\left(\sum_{m=1}^{M} \frac{s_m^+}{y_{m\ 0}}\right)} \tag{5}$$

$$s.t \sum_{k=1}^{K} \mathrm{z_k x_{nk}} + \mathrm{s_{nk}^-} = \mathrm{x_{n0}}, \quad \mathrm{n} = 1, 2\ldots, \quad \mathrm{N} \tag{6}$$

$$\sum_{k=1}^{K} \mathrm{z_k y_{mk}} - \mathrm{s_{mk}^+} = \mathrm{y_{m0}}, \quad \mathrm{m} = 1, \ldots, \mathrm{M} \tag{7}$$

$$\sum_{k=1}^{K} z_k u_{jk} = \lambda^* \mathrm{u}_{j0}, \quad j = 1, 2, \ldots, J\ \mathrm{z_k} \geq 0, \quad \mathrm{k} = 1, \ldots, \mathrm{K} \qquad s_n^-, s_n^+ \geq 0$$

According to the corresponding output set, in case of a permissible strong disposability of undesirable outputs, the unit $\mathrm{DMU_j}$, (j = 1, …,n) represents a production possibility set (PPS) of the sophisticated addition of slack-based inputs associated with great effectiveness determination. According to what is discussed in the weak disposability of outputs and the null-jointness, let x ∈ R_{mk}^+, y ε R_{sk}^+ and z ε R_{dk}^+, equivalent to the vectors of the first input and intermediate goods, with output in favor of DMU less than assessment k. The production process ends in order to remove the undesirable outputs. Association structure is used to address the competitive position of DMUs by some scholars after analysing many studies.

It means that it is separate from the study in terms of position capable DMUs with the SBM model (Färe et al., 2005). and (Zhou et al., 2006) define the weak disposability reference technology T, developed mainly to simultaneously produce desirable and undesirable outputs. The efficiency measure is given as:

$$SBEI_1 = \lambda^* \times \rho^* \tag{8}$$

It is important to note how $\mathrm{SBEI_1}$, regardless of being a standardised index, lies within the interval (0,1] and fulfills the property "the larger, the better," characterising it as a benefit type indicator. This paper takes into account the annual data from 2010 to 2018 for the BRI countries. The world bank indicators are used for collecting data regarding labor, capital and GDP, whereas the international energy agency database is used for data regarding the total energy consumption and CO_2 emission. Here, labor, capital, and energy consumption are considered the input variables, GDP as the desired output, and CO2 emission is considered the undesirable variable.

3.2. GMM model specification

It is essential to assess the models for any random or default correlation effect before we apply the panel or dynamic GMM to panel data. At this point, the values of the critical probability acquired from the Hausmann test prove the random effect of being better. With its relevance to other estimating methods, provide “effective” estimates, GMM is considered as one of the most common methods in the current literature of econometrics. Arellano and Bond (1991) argued that the GMM estimator, including the lagged endogenous variable as an explanatory variable, is more convenient for panel data because it yields more consistent and robust results in the presence of arbitrary heteroskedasticity. The dependent variable is affected by the changes occurring in one of the defining variables but adjusts with time to find a long-term balance. In the case of the panel data with the extension of panel studies, GMS umbrella OLS estimates and 2SLS techniques are applied to not just a single but the whole system of equations. As compared to the cross-sectional differences and stabilise estimators, this technique works better for panel data dynamics. Wooldridge (2001) confirms GMM models as a better tool for analysing panel data and the suitable method for panels with unprotected effects (Arellano and Bond, 1991) established how the GMM estimates applied well even with weak assumptions. Wooldridge (2001) defines the ability of GMM to not identify many parameters as one of its strengths. In cases, such as estimating the relationship between economic growth and energy variables, where models lack external variables, GMM is applicable Wooldridge (2001).

The GMM model can be represented as follows:

$$Y_{i,t} = \alpha + \beta\, Y_{i,\,t-1} + \delta\, X_{i,\,t} + \mu_{i,t} + \varepsilon_{i,t} \tag{9}$$

where the dependent variable for a country i at time t is $Y_{i,t}$, $Y_{i,\,t-1}$ is it its lagged value). The set of independent variables is given as $X_{i,\,t}$, the country-specific effects as $\mu_{i,t}$ and the error term can be defined as $\varepsilon_{i,t}$. In this study, the green economic performance (GEPI) is taken as the dependent variable, per capita education (PCEDU) and per capita R&D (PCR&D) as the set of independent variables $X_{i,\,t}$ (independent variables) and Industrial structure (INDS), GDP per land area (GDPPL), foreign direct investment (FDI) and urbanization (URB) as controlled variables. As a measurement tool for the GMM model, we use lagged independent variables. Table 1 is defining the variables used in our empirical analysis.

Although the variables are further explained with measurement units' help, few problems occur due to the balancing method, such as eliminating individual effects due to the contrast method. Secondly, the instrumental variable can reinforce the bad instrument problem when time variable "T" poses as a big problem. Considering the first difference of the single-step system GMM, it is said to have a negative relationship with the two System-GMMs. For better efficiency, The GMM estimator enables more tools (Hainaut and Cochran, 2018).

Some of the significant limitations of this study include limited data and lack of observation for the emerging economies (ie, panel imbalance). Secondly, some of the countries in our data sample have net energy imports constituting various proportions of their total energy use. Although a country's net energy import status remains unaffected by how we choose energy security indicators (Zhang et al., 2019a,b), assessing various energy security measures based on a country's net energy import status is another possible way to extend this research. Thirdly, in this study, energy prices are not considered, pertaining to the limited local data for some countries in the sample. A well-documented form of effects of energy prices on different economies is present in the study (see references in the “Introduction” section). This study is focused on energy security indicators, excluding energy prices.

Table 1
Definition of variables.

Type of variable	Symbol	Definition of variable
Dependent	GEPI	The green economic performance
Explanatory	PCEDU	Per capita education
	PCR&D	Per capita R&D
Control	IND	Industrial Structure
	GDPPL	GDP per land area
	FDI	Foreign Direct Investment
	URB	Urbanization
Instrument	GEPI (−1)	1-period lagged the green economic performance

Source: Authors compilation

4. Results and discussion

4.1. Green economic performance analysis

Ragwitz and Miola (2005) state that among the 29 countries in the EU, R&D and demonstration R&D have the lowest allocated budget (i.e., <10%). The energy industry is the central part of the R&D sector, where 65% of the allocated budget is used for photovoltaic technology, which is a balancing point. This low budget allocation is due to Europe's less inclination towards import-based economy (i.e., feed-in tariff, feed-in tariff premium, green certificates, tax incentives, grants) and environment-friendly policies (Meleddu and Pulina, 2018). The BRI countries has been divided in 3 regions.

Table 2 shows the efficiency score of the Middle East Region; UAE, Qatar and Saudi Arabia are the top performers, followed by Israel. In contrast, Egypt and Iran have the lowest efficiencies.

Results show that Qatar, Saudi Arabia, Singapore, and UAE are the top GEPI performers among the 28 countries of our study; China, Russia, and South Korea are the most improving countries based on the GEPI. The average fluctuation in GEPI indicates the upward transition of the BRI countries towards green development, except for Israel, Indonesia, Malaysia and the Philippines, whose GEPI has a gradual decrease from 2010 to 2018 (Xie et al., 2017). A uniform year-to-year decrease has also been observed. 2018 was the max-efficiency year with the GEPI score of 0.78, showing the maximum inclination towards green growth (Zhang and Li, 2018).

Table 3 shows the efficiency score of the South Asian region. India and Maldives are the top performers with score near 1, while Nepal, Pakistan, and Sri Lanka rank lower in the region.

Table 4 shows the East-East, North-East Asia and ASEAN Regions' efficiency score. Singapore is the only country with a best score throughout the period; South Korea, Russia, and China are at the top of the charts with a 1 in some years, while Malaysia follows a relatively good score throughout the period.

Public investment in the renewable energy sector increases employment (Lebelhuber and Steinmüller, 2019), improves the environment, and reduces the overall energy costs. Moreover, the state administration could play an essential part in demonstrating the change from consumption and production patterns to more environmentally friendly private sector options. The development of renewable energy competing with other main welfare actions (i.e., the economic efficiency of allocating public resources to photovoltaic solar panels) makes sense.

Table 5 represents the Central Asian region's efficiency score; Turkey was the top performer with an efficiency score between 0.65 and 0.95. Uzbekistan was the second, while Kyrgyzstan has the lowest score ranging from 0.65 to 0.69.

4.2. Full sample analysis of two-step system GMM

Table 6 illustrates the values obtained through econometric estimation tools. The GMM coefficient of estimation for R&D fiscal expense is 0.044, revealing a statistically positive and significant test with a value of over 5%. In contrast, the GMM coefficient of estimation for fiscal expense for education is 0.084, showing a significance at 1%.

Table 2
Efficiency score of the middle East region.

Year	Israel	Kuwait	Egypt	Oman	UAE	Qatar	Saudi Arabia	Iran
2010	1	0.83	0.62	0.77	1	1	1	0.6
2011	1	0.84	0.74	0.78	1	1	1	0.63
2012	1	0.85	0.5	0.77	1	1	1	0.71
2013	1	0.84	0.65	0.78	1	1	1	0.71
2014	1	0.84	0.75	0.78	1	1	1	0.73
2015	1	0.85	0.71	0.75	1	1	1	0.68
2016	0.93	0.84	0.9	0.74	1	1	1	0.73
2017	0.92	0.87	0.78	0.74	1	1	1	0.67
2018	0.92	0.85	0.84	0.75	1	1	1	0.72

Source: Authors' calculation

Table 3
Efficiency score of South Asian region.

Countries	Bangladesh	India	Nepal	Pakistan	Sri Lanka	Maldives
2010	0.47	0.67	0.37	0.66	0.63	0.87
2011	0.46	0.71	0.39	0.68	0.64	0.88
2012	0.45	0.69	0.52	0.67	0.65	0.87
2013	0.46	0.79	0.44	0.67	0.64	0.88
2014	0.45	0.79	0.41	0.67	0.64	0.88
2015	0.47	0.84	0.4	0.68	0.65	0.85
2016	0.51	0.73	0.38	0.69	0.64	0.84
2017	0.52	0.77	0.33	0.71	0.67	0.84
2018	0.54	0.76	0.38	0.72	0.75	0.85

Source: Authors' calculation

Chinese companies have not supported environmentally friendly technologies sufficient to respond to the demand in the R&D expenditures. When introducing cleaner production, countries face external and internal barriers; hence the composition effect surpasses the technique effect significantly (Li and Li, 2020).

The findings of the control variable fulfill the requirements of this analysis. From the industrial structure perspective, the industrial structure has adverse and statistically significant effects on green economic growth with coefficient values −0.324, −0.374, −0.294 and −0.297. These effects are due to the increased secondary industry pollution from excessive energy consumption (Shuai and Fan, 2020 and Shahbaz et al., 2018).

From the perspective of the percentage of green zones which has a significant impact of urban areas for optimizing environmental guidelines. These findings are consistent with previous studies (Shahbaz et al., 2018a), according to which the development of environmental policies can facilitate green economic growth. GMM demonstrates that the production scale effect shown by the GDPPL coefficient is statistically positive and significant at 5% or higher, which is in line with previous research (Jin et al., 2018). This implies that land is the fundamental distributor of all living activities and human development. In the meantime, the negative and statistically significant (at a minimum level of 5%) estimation results for the time-lag of independent variables is overwhelming, revealing the changing nature of the green economic growth(H. Sun et al., 2020) and (Alemzero et al., 2020).

4.2.1. Estimates for green economy analysis

The model shows satisfactory fitness obtained through the adjusted R-squared and significant coefficient. Regardless of the approach, with a significance level of 1%, all GMM estimates will have a negative and statistically significant impact on the share of public expenditure. The green performance indicators are ranged between −0.210 and −0.217. It is determined that up to a 7.7% increase in the green economy and a 4% decrease in carbon emissions may occur due to a 1% increase in the government's green expense, where the total government expenditure is constant. The Arellano-bound AR(1) value is between −6.814 and −6.782, while the Arellano-bound AR(2) value is between −0.567 and −0.583. One standard increase in the R&D expenditure standard deviation may cause a 10% reduction in the carbon concentration. Therefore, the quantitative effect of changes in the government spending structure appears to be substantial. Government size is measured as the ratio of total consumption expenditure to GDP and, all three estimators considering the heterogeneous areas' characteristics do not have any significant impact on any pollutants. The degree of correspondence in these findings is unexpected. Most of the carbon and lead is generated from power production and industrial processes. A significant portion of the present lead concentrations is due to industrial processes, as lead has been partially or entirely banned in gasoline since the mid-1980s. Therefore, this study considers air pollution like lead and carbon.

Table 5
Efficiency score of central Asia.

Year/ Countries	Turkmenistan	Kyrgyzstan	Turkey	Kazakhstan	Uzbekistan
2010	0.76	0.66	0.95	0.76	0.95
2011	0.76	0.65	0.95	0.75	0.86
2012	0.75	0.65	0.95	0.73	0.84
2013	0.73	0.67	0.85	0.75	0.80
2014	0.73	0.66	0.78	0.67	0.85
2015	0.79	0.65	0.78	0.68	0.87
2016	0.83	0.66	0.80	0.68	0.95
2017	0.81	0.67	0.77	0.67	0.95
2018	0.83	0.69	0.65	0.65	0.95

Table 4
Efficiency score of East-East, North-East Asia and ASEAN region.

Year	Malaysia	Philippines	Singapore	Thailand	Indonesia	Korea	Russia	China	Vietnam
2010	0.82	0.57	1	0.66	0.58	1	1	0.93	0.46
2011	0.83	0.58	1	0.65	0.73	1	1	0.93	0.5
2012	0.8	0.57	1	0.65	0.72	0.93	1	0.95	0.49
2013	0.81	0.58	1	0.67	0.62	0.95	0.97	0.98	0.49
2014	0.77	0.58	1	0.66	0.58	0.96	0.98	1	0.48
2015	0.76	0.55	1	0.65	0.58	0.96	1	1	0.5
2016	0.79	0.54	1	0.66	0.58	1	1	1	0.53
2017	0.79	0.54	1	0.67	0.58	1	1	1	0.52
2018	0.81	0.55	1	0.69	0.58	1	1	1	0.55

Source: Authors' calculation

Table 6
Main estimation results of one-step and two-step GMM.

	CER		MER	
	(1)	(2)	(3)	(4)
GEPI_lag1	0.3615*** (0.0014)	0.3827*** (0.0017)	0.3901*** (0.0023)	0.4155*** 0.0029)
IND	0.0286 (0.1551)			
IND_lag1		0.0342** (0.1137)		
PCEDU			0.0304** (0.0052)	
PCEDU_lag1				0.0795*** (0.0881)
PCR&D	0.0342 (0.0011)	0.0350** (0.0012)	0.0294* (0.0203)	0.0301** (0.0214)
FDI	0.0151 (0.0014)	0.0160 (0.0017)	−0.0209 (0.0159)	0.0241 (0.0022)
URBAN	−0.3251 (0.0445)	−0.3607 (0.0450)	−0.4251 (0.0624)	−0.4399 (0.0661)
GDPPL	−0.0293* (0.0046)	−0.0311* (0.0053)	−0.0413** (0.0058)	−0.0438*** (0.0059)
Constant	1.0384*** (0.1170)	1.0586*** (0.1225)	1.1112*** (0.0519)	1.1477*** (0.0701)
AR(1) test	−2.0632 0.023	−2.0841 0.023	−2.4149 0.019	−2.5243 0.013
AR(2) test	−1.1591 0.171	−1.2374 0.138	−1.2580 0.166	−1.3001 0.154
Sargan test	21.3797 0.068	19.9903 0.069	23.5612 0.11	18.5531 0.139
Wald test	176396 [0]	280449 [0]	192133 [0]	305156 [0]

Note: p-value in brackets and standard errors in parentheses; *p < 0.1, **p < 0.5, ***p < 0.01. Source: Authors' calculation.

Then we applied non-parametric statistical tests based on rank-sum equality, equality of distribution, rank comparison, and well-known one-way ANOVA to test the variance difference of both low and high GDP per capita countries. The results show that there is no statistically significant difference in the GEPI levels of both groups. It may be due to as technology advances or a specific data set. The technology can be a revolutionary factor that can help countries to improve their GEPI level. This means that the country with the highest GDP per capita may or may not be the highest. As technology advances, the per capita GDP of these countries may also significantly increase. Technology can be a revolutionary factor that can help countries improve their green economic performance level.

Table .7 shows the green economic performance index. The low GDP per capita countries have reasonable estimates in terms of composition and technical effects. The education expenditure coefficient of low GDP per capita countries is 0.215, which is significant at the 1% level, but in high GDP per capita countries, the value is reduced to 0.049, which is significant at a 5% level. The per capita research and development expenditure (PCRD) of the low GDP per capita countries are estimated to be 0.063. However, in high GDP per capita countries, the coefficient of PCRD expenditure is 0.025, which is insignificant at the 10% level. The decline in economic growth ultimately affects the education and R&D budget. The split analysis results confirmed heterogeneous composition and technological effects in countries with different GDP per capita.

The central government's regional policies, the social tolerance of pollution, the efficiency of local bureaucracy, and other unobserved regional specific factors, may lead to fiscal expenditures for the green economy different (Table 8). The level of fiscal expenditure for education and R&D rarely causes environmental pollution. In terms of R&D expenditure, Eastern China ranks first in terms of R&D level and share. The estimation results are shown in table 8 from where it is observed that the coefficients of fiscal spending on R&D are positive, having a 5% or greater significance level for every observation. Moreover, investing in R&D predominantly affects ordinary resources to promote green energy technology and innovation. However, in the case of restructuring the industry with upgraded technology, such investment is negligible compared to countries with plenty of resources.

Table 7
Test the differences in energy efficiency based on the material used.

Test statistics	GEPI	P-value
Mann-Whitney test	−1.378	0.176
Kruskal-Wallis rank equality test	1.897	0.176
K–S test for equality of distribution	0.0717	0.282
One-way ANOVA	0.0227	0.87

Note: GEIP shows green economic performance index.

4.2.2. *Human capital investment structure effect*

Although the share difference between the three regions is small, the gap in the level of R&D expenditure seems to be vast and long-lasting. Table 9 shows the sub-sample results based on the system GMM estimation. In the BRI region, education spending increased by 1%, green economy performance increased by 7.5%, and R&D expenditure increased by 5.4%. These estimates indicate that compared with the national average, the region has a relatively sizeable compositional effect. Compared with the complete sample results of green economic performance, R&D expenditures show a slight increase in the technical effect of −0.042. Even in more developed countries, the potential forces that hinder the transition from research funding to the adoption of clean technologies are still strong. The existing economic structure and looser environmental regulations have further reduced clean technologies' adoption rate, which is reflected in negligible technical effects. Among the developed regions, developing countries have the weakest ability to provide higher education. Economic growth dominates the region's environmental protection, and economic structural adjustment to human capital-intensive industries may take decades to achieve. The estimation results for public spending on education for low GDP per capita countries are significant at 5%level with a coefficient value of 0.04, high GDP per country is significant at a 1% level with a coefficient

Table 8
GMM estimate of green economic.

	(5)	(6)	(7)	(8)
GEPI_lag1	0.3711*** (0.0026)	0.4028*** (0.0031)	0.3996*** (0.0011)	0.4154*** (0.0013)
IND	0.0293* (0.0556)			
IND_lag1		0.0415** (0.0603)		
PCEDU			0.0322* (0.0046)	
PCEDU_lag1				0.0519*** (0.0054)
PCR&D	0.0410 (0.0069)			
FDI		0.0466 (0.0072)		
FDI*R&D			0.0912** (0.1120)	
FDI_lag1*R&D				0.1032** (0.0589)
URBAN	−0.2491* (0.0248)	−0.3157 (0.0346)	−0.3466 (0.0516)	0.0112 (0.1737)
GDPPL	−0.0193* (0.0177)	−0.0234*** (0.0186)	−0.0201** (0.0170)	−0.0355* (0.0199)
Constant	1.1383*** (0.0390)	1.2353*** (0.0490)	1.1099*** (0.0590)	1.0723*** (0.0590)
AR(1) test	−2.2932	−2.3024	−2.1575	−2.1235
AR(2) test	−1.3401 [0.1749]	−1.2552 [0.1411]	−1.2380 [0.1382]	−1.1895 [0.1312]
Sargan test	21.3771 [0.0752]	20.1098 [0.0706]	17.8685 [0.1123]	15.596 [0.1269]
Wald test	198472.3 [0]	300239.2 [0]	232216 [0]	291644.1 [0]

Table 9
Results of human capital investment effect.

	Low GDP per capita Countries	High GDP per capita Countries	Full sample
L.log(HCI)	0.700***	0.542***	0.735***
	−0.099	−0.09	−0.046
PCEDU	0.040**	0.035***	0.024***
	−0.018	−0.013	−0.008
Constant	0.810**	1.098***	0.637***
	−0.313	−0.251	−0.27
Control variables	Yes	Yes	Yes
Observations	108	144	252
Arellano-bond AR (1)	−4.092	−4.542	−6.501
	[0.000]	[0.000]	[0.000]
Arellano-bond AR (2)	2.153	1.35	2.391
	[0.031]	[0.177]	[0.017]
Sargan test	85.766	85.05	244.517

Note: p-value in brackets and standard errors in parentheses; *$p < 0.1$, **$p < 0.5$, ***$p < 0.01$.

value of 0.035. It is observed that estimation results for all the samples reached a 5% significant level or higher irrespective of the dependent variables.

4.3. Discussion

Carbon emissions positively correlate with energy consumption and R&D expenditure in the regions studied in this work. The BRI region is highlighted for quantity, with a lower value than the other two analysed areas, which are; the correlation between energy consumption and CO_2 emissions in the BRI region. This may indicate that the BRI region has less energy consumption. Similarly, due to China's high technological usage, R&D expenditure in the BRI region has a weaker correlation with carbon emissions than in China. Higher innovation results in better economic development, associated with higher energy consumption and more pollution.

The complex nature of impact formation reveals that the sample countries are heterogeneous and it is possible to explain this diversity in more detail. Firstly, all resource-rich countries have an equal effect on government education expenditure in reinforcing the accumulation of human capital. The government budget for education is already higher in these countries, the standard of education is good, and more competent human resource is developed (Akhtar et al., 2018). R&D expense positively correlates with the region's energy consumption. This work assesses the "Belt and Road" region through a time series of three variables (energy consumption, total R&D expenditure and carbon dioxide emissions). However, as economic growth is considered an explanatory variable for CO_2 emissions, and due to the direct link between economic growth and energy consumption, only one of the three variables is enough to improve the model's explanatory power. The purpose is to capture the effects of a period, make expenditures into applied technology, and ultimately affect the level of pollutant emissions because technology mergers do not happen immediately (Anser et al., 2018).

As expressed by the modified R square 0.086, the model has a high predictor capacity, and it explains more than 90% of the dependent variable variability. As for the model specification, the Sargan test value is 271.23. This value indicates the direct relationship of energy consumption with carbon emissions and the impact of R&D expenditure on Carbon emissions. This shows that R&D spending positively affects the European economy's environmental correction, thereby reducing CO_2 that are not related to the energy used. Innovation has the same effect on the two regions, reducing CO_2.

5. Conclusion and policy recommendations

The GMM analysis performed in this study using BRI countries' data show that both the composition and technology effects are present in achieving green growth goals. The composition effect in mitigating pollution and paving the way for a new form of economic growth. Technique or technology effect can ultimately help keep the pollution output ratio at a minimum. Moreover, Public spending on both the R&D of green energy technologies and human resources (education) appears to accelerate the growth of the green economy. The degree of such acceleration varies from country to country in terms of technology innovation and human resource accumulation. In light of the conclusion drawn, this study makes the following recommendations to the policymakers:

- Firstly, the BRI countries should assess the status-quo, set meaningful targets, and construct a useful index to monitor the level of green economic performance and the extent of green economic progress. Though there have been some measures to monitor energy efficiency and the degree of pollution and economic progress, they seem not adequate. Those measures should be replaced by a more robust and time-worthy indicator for the sake of real-time performance evaluation, which will help sort out any irregularities in the enforcement of local and international energy laws.
- Secondly, the authorities should restructure public spending and increase the allocation of funds towards public goods. Public spending on R&D and education has risen lately in BRI countries, but it is yet to reach developed countries' level. As this study shows that spending on education and R&D can foster green economic development, governments should allocate further funding to these two sectors. This will proliferate human resource mobilisation and technology innovation, which are found to be critical to green economic success.
- Thirdly, this study shows that public expenditure on green economic growth varies between the countries. The governments should not rely on a general idea instead formulate their country-specific strategic plan for higher benefits. The government should increase the allocation of public funds to local industries for green energy technologies development. Such funding should be governed strictly based on the expected outcome. Often, the fundings without project milestones tend to derail from the initial objectives essential for the public and nation's interest. Therefore, strengthening communication between the government funding agencies and the green energy sector could ensure a better understanding of each other's needs and expectations.
- Furthermore, government spending should focus on basic research and applied research as well through university-industry partnerships. In other words, government spending should continue to improve technology until it reaches a level where companies can adopt and commercialise. However, governments' technical education will affect the technological development of the industry, at the cost of not witnessing the increase of fundamental progress in the future, which may even serve future economic growth.
- Fourth, solely relying on public spending is not enough to reach the green development goals or the United Nations' Sustainable Development Goals (SDGs). Hence governments should provide incentive schemes to promote the private sector green finance. The private sector is reluctant to enter green energy infrastructure projects mainly because of the high-risk and low rate of return. New green energy infrastructures appear to produce spillover effects (Yoshino et al., 2019). Refunding a part of the tax increase due to this spillover effect is one way of increasing the rate of return of these green projects.
- Fifth, to reduce private green finance risk throughout the BRI countries, governments can implement de-risking tools, such as establishing a green credit guarantee scheme (Taghizadeh-Hesary

and Yoshino, 2019; 2020). A key strategy for reducing greenhouse gas emissions is to shift demand from carbon-intensive energy (mainly coal and oil) to "green" energy (ie wind, solar, biomass, environmentally friendly, renewable, and carbon-free energy). Demand-side policies may include strategies for technological choices, consumption, behavior, lifestyle, related production-consumption infrastructure and systems, service provision, and related social, technological transformation. The political challenge is to design cost-effective policies to move energy demand toward reduced energy use and more renewable energy. In an ideal world, such policies can effectively influence different consumer areas and target groups. The characteristics of such policies should be inclined towards sturdy, cheap, flexible, socially acceptable, fair, and have few unexpected side effects, such as unwelcome distribution or rebound effects. Simultaneously, if energy suppliers are involved, these tools should be easy to implement and not excessively distort market competition.

- Finally, several renewable energy audit reports, including by IEA for the year 2020 across the globe, suggest that the green sector is significantly affected by the Covid-19 pandemic. However, by the initiation of the vaccination, the impact of Covid-19 on renewable energy technologies adoption in 2021 onward is expected to be insignificant. Therefore, the stimulus packages and new economic revival plans should resume the positive growth of green economic development across the world.

CRediT authorship contribution statement

Dongyang Zhang: Conceptualization, Methodology, Writing – review & editing. **Muhammad Mohsin:** Conceptualization, Data curation, Software, Writing – original draft. **Abdul Khaliq Rasheed:** Writing – review & editing. **Youngho Chang:** Investigation, Writing – review & editing. **Farhad Taghizadeh-Hesary:** Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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