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RETRACTED: Public Spending, Green Finance, and Zero Carbon for Sustainable Development: A Case of Top 10 Emitting Countries

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In general, the public expenditure on schooling, science, and research and development (R&D) is thought to have a positive effect on the development and sustainability of an economy, but such evidence is lacking in the developing and developed countries, especially in the top 10 CO_2-emitting countries. This study investigates the impact of public spending and green finance on environmental sustainability, using the ordinary least square method and data envelopment analysis, which uses the panel data from selected countries from 2008 to 2018. Results reveal a fluctuating green economic growth index, which was due to the non-serious existence of government policies. More precisely, a 1% increase in gross domestic product (GDP) growth increases the carbon emissions by about 0.40%, whereas the rise in coal consumption decreases environmental efficiency by about 0.88%. We also concluded that 0.95% GDP growth and economic development significantly enhance environmental emissions, whereas 0.5% of renewable energy consumption decreases the negative impact of environmental pollution. Furthermore, a 1% growth in renewable energy consumption improved environmental efficiency by 0.58%. Furthermore, the analysis demonstrates that the public expenditure on human capital and renewable energy (R&D) leads to a productive green economy through labor, and technically advance developmental practices, with varying consequences in distinctive countries.

Keywords: green energy finance, public spending, top 10 CO_2 emitting countries, DEA, OLS

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1 INTRODUCTION

CO_2 emissions account for 70% of global greenhouse gas (GHG) emissions, making it a major economic and social concern (Zhang Y. et al., 2021). According to the Organisation for Economic Co-operation and Development (OECD)'s 2013 report, the producing value-added ratio to large contaminant manufacturing is used to measure environmental protection levels (Yumei et al., 2021b). A thorough investigation of environmental efficiency was carried out by taking the above three manufacturing pollutant emissions and the specifics of each nations' industrial production volume to verify the consistency of energy and economics (Iqbal et al., 2019b). The International Energy Agency (IEA) defines energy efficiency as the ability to provide additional services for identical or rarer energy inputs. Economic growth and energy security have been linked to increased energy efficiency because of rapid climate change (Huang et al., 2022). Many countries, both developed and developing, have made it a priority to decrease carbon emissions and enhance energy efficiency to slow down the pace of global warming.

An assessment of energy efficiency and comparisons between emission reduction, transportation, and agriculture are necessary to achieve economic development objectives (Latif et al., 2021). As a result, in order to accurately calculate and recognize the majority of energy efficiency, comparisons must be made both vertically and horizontally in terms of emission-lessening planning and energy efficiency (Abbas et al., 2022). Energy efficiency has become an emerging problem for the industry as a result of new environmental regulations implemented by governments and growing pressure from local, national, and international communities to reduce GHG emissions (Mohsin et al., 2021). People are becoming increasingly concerned about the amount of energy they use and amount of CO_2 they emit as a result of GHG emissions. A wide range of economies is represented on the list of the world's top CO_2 emitters.

Economically, the public investment in research and development (R&D) is justified not only to increase employment and combat climate change but also to potentially lower overall energy costs (Abbas et al., 2021). Energy production and consumption based on conventional sources increase negative externalities, resulting in a market failure that necessitates public investment (Abbas et al., 2020). This concern arises when specific components of government spending have a greater impact on green economic activity than others. The economic efficiency of a country can be increased by altering the amount and composition of total public R&D spending.

Developing countries endorse the development of broad markets through cooperative collaboration in the energy and infrastructure sectors (Brahmasrene et al., 2014)(Yumei et al., 2021a). The attention toward the new industrial production sector is increasing rather than agriculture in developing countries in Asia and Africa are relying on their manufacturing sectors to produce a significant contribution to meet their development goals (Chen et al., 2019). Emerging countries have intensified their dependence on energy supplies to produce a more consistent and better production (Baloch et al., 2020). Irrespective of the fact that numerous scholars suggested a focus on environmental problems in the top 10 CO_2-emitting countries area, the study is still in its early stages (Morfeldt and Silveira 2014). Green economic development has increased as a result of dependence on the manufacturing part and Non-renewable energy (NRE) resources; however, continuous environmental deterioration results in upcoming risks (Iqbal et al., 2021c). Conferring to the existing studies, the top 10 CO_2-emitting countries' project will greatly boost the economic development of Belt and road initiative (BRI) member countries. Energy and living conditions should be utilized to meet the development goals. Some factors like the dependency on Non-renewable energy, inadequate public investment in the R&D sector, and improper environmental emulsion contribute toward the less developed green economy (Sueyoshi et al., 2017; Aloui et al., 2016). This analysis constructs a "green economic growth index" using the common path distance approach. The considering index development method makes changes in the economy's growth, capital, and environmental situation (Bhattacharyya and Bhattacharyya 2019). The variations in this index are closely watched in the overall analysis. The investigation follows the creation of the index, which is applied to calculate the influence of education and R&D spending on green economic development using a twofold structure known as the ordinary least square (OLS) process. The technological and informational influence has positive statistical effects, while the formulation effect was observed to have a larger influence than the technological effect throughout the analysis. This research also considers the effect of the powerful potential sources of public investment on green economic development. According to the research findings, public expenditure on education will boost human skills. Similarly, public investment in R&D will boost technical innovation (Sarangi et al., 2019).

Our contribution lies in the following aspects: 1) by assessing and doing a comparison of the triple mandates of top 10 CO_2-emitting countries with the OLS model, which maximizes green economic performance; 2) by developing energy policies into emission reduction by measuring energy and environmental efficiency; and 3) from 2008 to 2018, this research examined how the top 10 industrialized nations fared on environmental metrics such as carbon emissions, energy use, and economic growth. To that end, researchers figured out how much they could cut back on carbon dioxide emissions and primary energy consumption. Last but certainly not the least, this study's contribution is that it provides an example of how the Data envelopment analysis (DEA) method can be used to find energy, financial, and ecological efficiency by using the top 10 CO_2-emitting nations in the globe as a case study. This research contributes to the body of knowledge by providing useful information. The findings of this analysis confirm the importance of government expenditure effects on the green economy movement. Regardless of whether or not a consistent analysis proves it, government spending affects the pricing process. Renewable energy and public investment in R&D have an enormous potential to stimulate economic growth and alleviate poverty. Since 2000, public R&D spending has increased by 20% (in real terms); it peaked in 2008 and then gradually decreased to $253 billion in 2013 (Yumei et al., 2021a).

Section 2 discusses the non-radial distance function method, **Section 3** gives an outline of the observational findings, **Section 4** elaborates on the mechanism review and primary scientific observations, and **Section 5** focuses on the interpretation and policy proposals.

2 LITERATURE REVIEW

As a result of human activities, such as the greenhouse effect, environmental issues have become increasingly prominent. Many countries are working to reduce their carbon dioxide emissions in order to reduce the effects of climate change. Increasing GHG

TABLE 1 | Top 10 CO_2 emitter countries in 2018.

Country	CO_2 emission (BMT)	Change
China	8.96	51.87
United States	4.89	11.50
India	2.36	100.51
Russia	1.47	5.42
Japan	1.09	9.60
Germany	0.69	11.12
South Korea	0.67	32.40
Iran	0.63	54.82
Saudi Arabia	0.54	56.91
Canada	0.52	1.52

debates and the major contributor of global warming carbon dioxide emissions, cement production, fossil fuel combustion, and land-use change (Iqbal et al., 2021b) have led scientists to believe that humans are the primary source of global warming (such as deforestation). Researchers, scientists, and policymakers have come to the conclusion that excessive emissions of GHGs from industrial processes are to blame for global warming (Gao et al., 2016), and that this will have negative consequences for the long-term progress of human society (Shahbaz et al., 2020). This means that there is a consensus among them on the need for low-carbon reforms.

Reducing GHG emissions and the demand for energy has long been touted as an achievable and cost-effective goal in the context of environmental protection (Wu et al., 2022). The oligopoly's market structure has been characterized as price contingent due to competition. The fear of competitors' reactions to price changes can act to restrict the demand curve model, even though the oligopolistic enthusiasm for price tackiness is not based on the critical assumptions of the demand curve model (Yu 2022). Inflexibility in pricing is not a difficult concept to grasp, but the market's activity can mimic price rigidity. Since the supply-and-demand nexus of the market is so concerned with the fairness of price adjustments, it is evident that the market is oligopolistic (Li et al., 2021). As a result of these price changes, customers were made aware of the dangers of market power abuse. The monopolistic market structure's guidelines necessitate a substantial regulatory framework for the market. A conservative market is supposed to have quick and immediate reactions to changes in energy prices and demand changes (Zafar et al., 2022).

According to the current economic and environmental conditions, energy reforms are necessary. Subsidy reforms should be implemented in order to bring down energy prices. A price increase may be a viable option, but there are a number of economic and social factors that complicate the process (Yam et al., 2021). With the rise in the cost of energy and development of more energy-intensive technologies, it is possible to improve energy efficiency. For energy efficiency to be achieved, subsidy reforms are required. Investing 20% of the savings from subsidy reforms in energy efficiency programs and renewable energy projects could reduce global emissions by 1%. More than 2°C above pre-industrial levels, and preferably below 1.5°C, is the goal of the COP. In 2005, the Kyoto Protocol's Paris Agreement came into effect (Zhang and Chen 2020; Naveen Babu et al., 2021). The Chinese economy has grown at an average annual rate of 9.5% over the past 20 years. Concerns about the environment accompany this rapid economic growth. Fog, haze, and smog have plagued many Chinese cities in recent years, particularly in 2013, as a result of increased energy use and pollution discharge.

To see how these top ten emitters have responded to the Kyoto Protocol, look no further than **Table 1**. Double-digit declines were seen in the United States as well as Germany and Japan. After the Kyoto Protocol, the rest of the countries increased their emissions. The US shale gas boom and renewable energy growth in both countries have contributed to this shift, but the instant growth of renewable energy use in both countries has minimized the demand for coal most significantly.

Per capita, the carbon dioxide emissions in the United States in 2018 amounted to 16 metric tonnes while China's emissions per capita amounted to only 5 kg. This means that the United States is liable for its share of environmental CO_2. Over the past decade, the top 10 emitters have collectively increased emissions by 2.2% from 2012 to 2013. A total of 4.3% and 1.4%, respectively, were the greatest single-year surges in GHG emissions during this period (Tong et al., 2018). Even though the largest emitters' emissions rose from 2012 to 2013, if we look out a decade, their total emissions will be unchanged. This is when US emissions peaked, while EU3 continued to decline steadily at that time. Other countries, such as Russia and Canada, have also stabilized emissions over the past decade. Even as the global economy grew over the same period, the carbon dioxide emissions from the energy sector remained the same, according to the most recent data. Because this is a positive development, the data on other types of GHGs are still pending, so we cannot say for sure if the current trend will continue or not. CO_2 is decoupled, as has been demonstrated in 21 countries.

The legally binding emission reduction targets for almost all of these countries are in place. In terms of global CO_2 emissions, China (a developing economy) currently holds the top spot with a 27.8% share, while Canada ranks 10th with a 1.7% share. To put it in another way, climate change and the environment are global problems that both developing and developed economies have a role to play in the sustainable development process by reforming their environmental and economic management programs (Zhao C. et al., 2022). Economic–environmental reforms and energy efficiency have received a great deal of attention in the last decade. One by one, the above-mentioned studies have brought these issues to light.

The author Shipalana (2020) found that the energy efficiency levels in Mediterranean nations are high and have decreased over time, as documented in methodological literature, using a truncated regression on the efficiency score of the DEA bias correction for environmental variables. The use of renewable energy, per capita GDP, and population density were also found to have an effect on efficiency. According to provincial data, a study by Zhang et al. (2021a) found that China's service industries are more efficient in terms of CO_2 emissions than the country's manufacturing sector. DAE was proposed by Chien et al. (2021) and applies to developed countries (excluding Japan and the United States) only. Environmental data analysis (EDA) was developed to measure the link between environmental and economic efficiency. Carbon dioxide emissions and GDP are the primary outputs of several studies that examine the inputs and outputs of capital investment, energy consumption, and labor. All of these factors are critical. Consider seven factors when looking at it from the provincial perspective.

3 DATA AND METHODOLOGY

3.1 DEA Approach and Green Economy as Indicator

In the slack-based system Slack based Model (SBM), data-driven methodologies are used to weigh multidimensional metrics objectively. Using a special type of output feature to assess efficiency is not required in all cases, however. Additionally, Nassiry (2018) provides recommendations for performance management. A method for determining slacks was defined by Zhang et al. (2021b), and they discovered that it was the primary cause of insufficient input utilization. Considering the case of a production method that manufactures both favorable and unfavorable outputs at the same time, $\mathbf{X} \in \mathbf{R}_+^N$, $\mathbf{Y} \in \mathbf{R}_+^M$, and $\mathbf{U} \in \mathbf{R}_+^J$. The following is an explanation of the production technology:

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

The production theory is known as the bounded and closed collection theory because of the closeness of T's performance. To put that into perspective, there can only be so many products from so many inputs. Using the DEA method, researchers like Zhang et al. (2021b) and Chien et al. (2021) have recently published studies on this topic that found that recycling and waste disposal provide the best opportunities for reducing emissions while also reducing energy consumption. DEA was used by Zhong et al. (2022) to examine the link between environmental regulation and China's use of fossil fuels. According to XimeiZeng (2022), the interest for saving energy and CO_2 emission decline rises due to improvements in ineffective decision-making units (DMUs) during the complex process of chemicals. Energy efficiency in provincial industries is first assessed using the DEA method. DAE was used to evaluate the ecological and energy efficiency of complex chemical practices, and it revealed that improved inefficient DMUs have increased the potential for energy conservation and carbon reduction.

If all desirable and undesirable outputs are considered "weakly disposable," it is possible to reduce unwanted outputs without affecting favorable outputs, according to a statement. An undesirable output is necessary to produce desirable ones, as stated in (ii). In the following output sequence, this method is also explained.

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

P(x) describes all possible outputs with x as the output variable. With x as the primary main variable, the transitional dealings z are constructed. The transitional goods build the final productivity vector y by considering the essential vectors of the subsequent stage. The deficit in the central trial (Gao et al., 2022) may affect the overall impact (Zhao X. et al., 2022). The new DEA model tests the energy performance of human DMU in the detached feature of model (2) in light of rare casual circumstances. The constraints in models 1 and 2 illustrate similar yet non-identical properties. On the other hand, T(y, u)P(x) (x, y, u) (x, y, u) (x, y, u) (x, y, u) (x, y, u) (x, y); however, the processing technology T has been theoretically well defined, it cannot be specifically implemented in functional use, and the undesirable outputs' vigorous disposability is invalid while considering T, although P(x) may be called an environmental output collection. After recognizing energy conservation as an often employed and monotonous process, the SBM DEA technique is used to describe the key events for DMUs. Using the best practices in SBM, a limiting scenario for core processes is given (Martínez-Avila et al., 2022). The relationship between the Shephard distance function and T can be thought of as an interpretation of the traditional single output manufacture functions (the directional distance function).

It becomes simple to quantify the application of distance functions when their parametric or nonparametric conditions are considered (Seiringer et al., 2022). Martínez-Avila et al. (2022) established the following data on the vectors of inputs and desired outputs: reflecting k = 1, 2, . . ., K DMUs and for DMUk. Here, the vector $V_k = (v_{ki}, \ldots, v_{kn})$ is substituted to discriminate between the input and outputs where X_k and Y_k are input and output vectors correspondingly by $X_k, \ldots, Y_k = X_{k1}, \ldots, X_{km}, Y_{k1}, \ldots, Y_{ks}$ (xk1,⋯,xkm,yk1,⋯,yks). The inputs vector $X_k = (X_{k1}, \ldots, X_{km})$ accustomed to developing the output vector $Y_k = (Y_{k1}, \ldots, Y_{ks})$. The inputs $X \in R_+^P$ and outputs $X \in R_+$ consequently, the production is the set of inputs and outputs of potential combinations.

$$\begin{aligned} &\mathrm{S} = \Big\{(\mathrm{X}, \mathrm{Y}):\ \mathrm{S} = \textstyle\sum_{k=1}^{K} x_{ik} z_k \le x_i,\ \ i = 1, \ldots, m \\ &\mathrm{S} = \sum_{k=1}^{K} y_{rk} z_k \le x_r,\ \ r = 1, \ldots, S \\ &\mathrm{S} = \sum_{k=1}^{K} z_k = 1,\ \ i = 1, \ldots, m \\ &z_k > 0,\ k = 1, \ldots, K\} \end{aligned} \tag{3}$$

With **Eq. 3**, the DEA range adjusted model as the constraint can be initiated.

$$\begin{aligned} &\max \frac{1}{m+s}\left(\textstyle\sum_{k=1}^{K} \frac{S_i^-}{R_i^-} + \sum_{k=1}^{K} \frac{S_r^+}{R_r^+}\right) \\ &\mathrm{S} = \sum_{k=1}^{K} x_{ik} z_k + S_i^- = x_{0i},\quad i = 1, \ldots, m \\ &\mathrm{S} = \sum_{k=1}^{K} y_{rk} z_k - S_r^- = y_{0r},\quad r = 1, \ldots, S \\ &\mathrm{S} = \sum_{k=1}^{K} z_k = 1 \quad\ i = 1, \ldots, m \\ &z_k > 0,\ S_i^- > 0,\ S_r^- > 0 \end{aligned} \tag{4}$$

where $\mathbf{x_{oi}}$ is i-th input and $\mathbf{y_{or}}$ r-th output for entity $\mathbf{o}(\mathbf{o}) \in \{\mathbf{1}, \ldots, \mathbf{K}\}; \mathbf{R_i^-}$ and $\mathbf{R_r^+}$ demonstrates the ranges for output r and input i, which can be defined as $\mathbf{R_i^-} = \mathbf{max}\{\mathbf{x_{ki}}, \mathbf{k} = \mathbf{1}, \ldots, \mathbf{K}\} - \mathbf{min}\ \{\mathbf{x_{ki}}, \mathbf{k} = \mathbf{1}, \ldots, \mathbf{K}\}$ and $\mathbf{R_i^+} = \mathbf{max}\{\mathbf{y_{ki}}, \mathbf{k} = \mathbf{1}, \ldots, \mathbf{K}\} - \mathbf{min}\ \{\mathbf{y_{ki}}, \mathbf{k} = \mathbf{1}, \ldots, \mathbf{K}\}$. The primary objective of this DEA model is to measure inefficiency in energy through the slack-based measurement of each entity. The constraints choose the maximum decrease that possibly forms the highest extension and decrease in outputs and inputs that are predictable. Thus, the frequency of a variable range to zero indicates that entities have zero value, and they could be excluded in EVI. The slacks' inputs and desired outputs are not included in the model, regardless of applicability. Even if one DMU has a stronger collection of inputs and desirable outputs than the other, the energy performance of the two DMUs will be the same because of this mechanism. Built a system to resolve this shortcoming.

$$\rho^* = \min \frac{1 - \frac{1}{N}\sum_{n=1}^{N} s_n^- / s_{n0}}{1 + \frac{1}{M}\left(\sum_{m=1}^{M} \frac{s_m^+}{y_{m0}}\right)} \tag{5}$$

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

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

$$\sum_{k=1}^{K} z_k u_{jk} = \lambda^* u_{j0}, \quad j = 1, 2, \ldots, J \tag{7}$$

$$z_k \geq 0, \ k = 1, \ldots, K \quad s_n^-, s_n^+ \geq 0$$

In the case of allowable high disposability of undesirable outputs, with a performance in support of DMU less than evaluation k, as discussed in the poor disposability of outputs and null-jointness, the processing method comes to a close with the elimination of unnecessary outputs. After reviewing several articles, several researchers have decided to use the association method to discuss the competitive status of DMUs.

It implies that it is distinct from the SBM model analysis concerning the capable role of DMUs. The poor disposability reference technology T was designed primarily to achieve both desirable and undesirable results. The performance metrics are as follows:

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

It is worth mentioning that, while being a standardized measure, SBEI1 falls within the interval (0,1) and has the property "the greater, the stronger," suggesting that it is again from the predictor.

3.2 Ordinary Least Square Method Model Specification

Before applying the OLS to panel details, it is critical to search the models for any random or default association effects. The results of the Hausmann test show that doing better is more likely to happen by chance. Due to its similarity to other estimation methods and potential to produce "efficient" estimates, OLS measured one of the more popular approaches in the existing studies in econometrics. It is more convenient to use a lagged endogenous variable as an explanatory variable in panel data. According to Arellano and Bover (1995), it provides more reliable and stable findings in the presence of subjective heteroskedasticity. This approach performs well for panel data dynamics than cross-sectional variations and stabilizes estimators. OLS models, according to Hansen (1999), are a well-improved medium for analyzing panel data and the best approach for panels with uncertain effects. Hansen (1982) demonstrated how the OLS calculations performed well, even though the assumptions were poor. One of OLS's benefits, is its capacity to not specify several criteria where models ignore external variables, such as when calculating the connection between economic development and energy variables.

TABLE 2 | Definition of variables.

Type of variable	Symbol	Definition of variable
Dependent	FS	Fiscal spending
Explanatory	GF	Green finance
	CO_2	Carbon emission
Control	GEP	Green economic performance
	GDPPC	GDP per capita
	FDI	Foreign Direct Investment
	PCR&D CO_2	Per capita R&D
Instrument	FS(-1)	1-Period lagged fiscal spending

Source: Authors compilation.

The OLS model can be signified below:

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

where Y (i,t) is the dependent variable for a country I at time t and Y (i,t-1) is the lagged value for a country i at time t. X (i,t) denotes the collection of independent variables, _(i,t) denotes the country-specific consequences, and (i,t) denotes the error name (i,t). The dependent variable in this study is spending (FS), with green finance (GF) and CO_2 emission (CO_2) as independent variables X (i,t) (independent variables), per capita research and development (R&DPC) and green economic performance (GEP), gross domestic product per capita (GDPPC), and FDI as controlled variables. We use lagged independent variables as a calculation instrument for the OLS model. The variables used in our analytical research are described in **Table 2**.

While the factors are better illustrated with the aid of measuring units, the balancing process has a few drawbacks, such as the elimination of individual results owing to the comparison method. Second, where the time variable "T" is a major issue, the instrumental variable will exacerbate the bad instrument situation. The single-step method OLS is claimed to have an unfavorable interaction with the two-step system OLS after considering the first distinction. More methods are available with the OLS estimator for performance improvement.

There are two major flaws in this study: omitting minor details and ignoring developing economies (i.e., panel imbalance). For the second time, several countries in our sample have significant net energy imports, accounting for varying percentages of total energy use. Assuming that the country's net energy import status

TABLE 3 | Values of descriptive statistics.

	Energy Use		CO_2		GDP		Population		GDPPC
	Avg	GR (%)	Avg	GR (%)	Avg	GR (%)	Avg	GR (%)	
Iran	25.67	3.50%	284.44	2.40%	1423.03	2.78%	46.52	−0.02	27879
Canada	334.00	0.70%	540.00	1.44%	1806.79	2.08%	35.88	1.99	46791
China	3013.94	4.10%	9184.02	0.07%	8934.85	6.94%	1371.86	0.165	7954
Germany	326.9	0.21%	765.44	−0.95%	3716.02	1.95%	81.168	0.62	44519
South Korea	285.8	1.30%	658.26	1.26%	1269.89	3.03%	50.48	0.51	27631
Russia	687.64	2.56%	1517.8	0.02%	1678.59	−0.19%	144.22	0.17	11796
India	690.66	5.30%	2151.4	4.98%	2302.06	7.33%	1308.65	1.16	1658
United States	2231.44	0.74%	5220.16	−1.05%	16581.96	2.29%	321.46	0.74	56208
Japan	457.72	-1.40%	1212.08	−1.97%	6003.19	1.09%	127.86	−0.12	38106
Saudi Arabia	255.22	4.50%	575.46	2.74%	666.77	2.14%	31.45	2.41	22214

is not affected by our choice of energy security metrics. Additionally, it is possible to expand this study by evaluating various energy security initiatives for countries that import a large portion of their energy needs. Finally, since some countries in the sample have restricted local records, in this analysis energy prices are not considered. The research includes a well-documented method of energy price effects on various economies. The emphasis of this analysis is on energy protection metrics rather than energy prices.

3.3 Data Sources

The annual data for the top 10 CO_2-emitting countries from 2008 to 2018 were included in this article. The data on labor, money, and GDP are collected using World Bank indices, while the data on gross energy demand and CO_2 emissions are collected using the IEA database. In this case, the input variables are labor, money, and energy use, GDP is the optimal output, and CO_2 emissions are the unwanted variable.

4 ANALYSIS AND DISCUSSION

4.1 Green Economy Performance Analysis

According to (Iqbal S. et al., 2021), R&D has the bottom-allotted expenditure (i.e., 10%) of the developing and developed countries. The energy business is a key part of the R&D market, with photovoltaic technology accounting for 65% of the expenditure, which is a complementary stage. Throughout the last half-century, global economic growth has been tremendous. Growth rates in energy consumption range from −1.40 to 5.30, while growth rates in CO_2 emissions range from −1.05 to 4.98.

According to **Table 3**, economic and energy efficiency assessments, as well as the factors that influence them, have been thoroughly studied in the existing literature, but more research is needed. As a first step, it is necessary to understand how technology and the environment interact to provide empirical evidence for developing or adjusting green energy development strategies; on the other hand, existing research mainly focuses on popularizing the technology, which cannot reveal the regional energy and environment level. Another issue is the absence of an assessment of the interrelationships between energy efficiency, economics, and the environment. For the period from 2013 to 2017, the top emitters of carbon dioxide were China, Japan, and Saudi Arabia; Russia was ranked as the least efficient. In the last 5 years, Canada and Iran have made significant progress.

Our findings prompted us to wonder if the final price is determined by the total cost of the product. As perfect competition necessitates that all producers have similar cost curves, the primary energy market does not always behave as if it is a competitive market. A lack of competition is resulting from high transportation costs, which are higher than the ex-works price of a product like wood or lignite. Special subsidies and taxes, as well as price agreements and cartels, can also distort the market. Consequently, the price of the final product may be indistinguishable from the taxes, rents, and subsidies that go along with them. Among the major assumptions of CERM is that all factors of production except land are characterized by energy, or can be expressed in energy equivalents. The land provided crops, wood, raw materials, cattle, and other resources. In spite of this, human effort, energy, and machinery would leave that source untapped.

The findings show that energy prices have a significant impact on patterns of energy consumption, which, in turn, affects the emissions of GHGs as a result of energy use. The theory of neoclassical economics states that when the price of a commodity rises relative to its substitute, the demand for that commodity decreases. Regardless of how inefficient the Chinese market is, energy can be classed as a resource commodity here. As a result, Chinese manufacturers have the option of substituting energy-saving technologies for traditional methods of increasing production, such as changing the nature of the workforce. In order to reduce carbon dioxide emissions from energy consumption, these kinds of efforts are necessary. The energy industry's consumption patterns could be reshaped, resulting in lower GHG emissions if market-oriented reforms are accelerated and government control is reduced. Increasing the positive spillover effects of the energy market factors, the ability of the energy market to reduce CO_2 emissions as a result of energy consumption may be used to promote a national concept of open markets with fewer trade barriers. The lack of strict environmental regulations may be compensated for by this model.

TABLE 4 | Energy efficiency score.

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Iran	0.51	0.49	0.51	0.53	0.55	0.53	0.52	0.51	0.52	0.53	0.54
Canada	0.42	0.41	0.43	0.43	0.435	0.47	0.46	0.45	0.47	0.47	0.48
China	1	1	0.97	1	1	1	1	1	1	1	0.98
Germany	1	1	1	1	0.98	1	1	1	0.56	1	1
India	0.42	0.41	0.42	0.42	0.48	0.4	0.48	0.47	0.5	0.5	0.52
Saudi Arabia	0.65	0.67	0.66	0.67	0.675	0.61	0.62	0.61	0.71	0.69	0.71
South Korea	0.53	0.54	0.54	0.54	0.57	0.53	0.53	0.52	0.53	0.55	0.57
United States	0.55	0.57	0.58	0.61	0.61	0.55	0.56	0.54	0.56	0.55	0.54
Japan	1	1	1	1	1	1	1	1	1	1	1
Russia	0.52	0.51	0.51	0.53	0.54	0.48	0.48	0.48	0.49	0.48	0.51

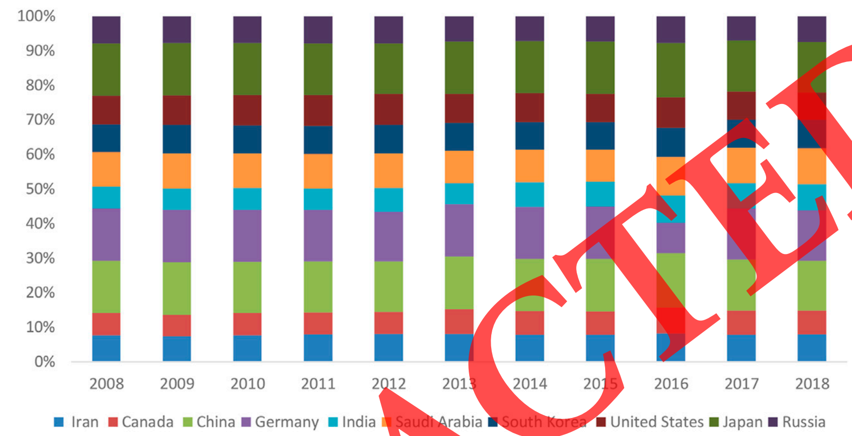

FIGURE 1 | Energy efficiency score.

As can be seen in **Table 4**, the ten countries with the highest CO_2 emissions have the best energy efficiency. Coal's demand may rise if crude oil's price rises because there are so many alternatives in the energy sector, such as natural gas and electricity. To keep this from happening, the cost of all nonrenewable resources must be raised proportionately, and consumers must be subsidized or otherwise encouraged to switch to more efficient renewable energy sources. Countries that emit the most carbon dioxide per capita are Saudi Arabia (third), Japan (fourth), and China (sixth). Similarly, Russia has the highest primary energy consumption efficiency, with a score of 0.449, making it the country with the highest energy intensity. The time coefficient indicates that technological advancements will lead to an increase in energy consumption. As a result, policies aimed at raising the cost of energy can help reduce energy intensity. Because of the low cost of energy, businesses and factories are not investing in energy efficiency or energy-efficient technologies properly. An illustration of the energy efficiency score's visual representation can be seen in **Figure 1**. Since companies are spending so much money on new technologies, the technological gap between developing and developed countries has grown. Energy efficiency can be affected by changes in oil prices, according to our findings. Restrictions on oil and gas prices have been a flashpoint for

TABLE 5 | Top 10 countries' ranking score.

Sr. No	Country	Rank
1	Japan	1
2	Saudi Arabia	1
3	Germany	1
4	China	1
5	United States	0.55
6	South Korea	0.55
7	Iran	0.53
8	India	0.50
9	Russia	0.48
10	Canada	0.47

TABLE 6 | Descriptive statistics.

	Population	Energy Use	GDP	CO_2
Max	1,386,395,000	3,051	1.94854E+13	9,838,754,028
Min	18,037,776	212	162,390	572,782,585.8
Average	346,899,424.5	870.3	4.71659E+12	2,376,848,085
SD	515,133,085.7	919.6204	5.95477E+12	2,840,413,837
Kurt	1.154077966	2.146592	2.485672997	4.396359334
Skew	1.803495758	1.814325	1.860878466	2.210077835

TABLE 7 | Efficiency of CO_2 emission for top 10 CO_2 emitter countries.

Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Iran	0.53	0.46	0.47	0.53	0.51	0.45	0.48	0.47	0.49	0.47	0.51
Canada	0.44	0.41	0.43	0.43	0.47	0.48	0.49	0.50	0.51	0.52	0.49
China	0.99	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Germany	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	0.56	1.00	0.97
India	0.43	0.41	0.42	0.42	0.48	0.40	0.51	0.52	0.53	0.54	0.53
Saudi Arabia	0.66	0.68	0.66	0.71	0.68	0.61	0.62	0.61	0.71	0.69	0.72
South Korea	0.58	0.54	0.54	0.57	0.59	0.61	0.63	0.59	0.56	0.56	0.54
United States	0.58	0.57	0.58	0.61	0.61	0.55	0.56	0.54	0.56	0.55	0.54
Japan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Russia	0.55	0.56	0.57	0.58	0.56	0.54	0.52	0.50	0.49	0.48	0.52

protests around the world in 2018, including in countries such as Haiti and France. **Table 5** lists the top ten economies in terms of CO_2 emission levels.

The descriptive statistics for the data are shown in **Table 6**. Corporate tax revenue can be redirected to carbon reduction and energy efficiency R&D, or tax burdens can be eased to encourage this research. In sectors where the additional costs of low-carbon technology choices are comparable to tax revenues, this may help alleviate some of the challenges to tax implementation. Host governments, however, must make advance payments in order to be effective because technology investment takes place in advance. **Eq. 4** calculates the potential energy savings (PES) of the less efficient countries. At a PES value of 40.2, the United Kingdom scored the lowest. As a result, the United States' overall energy consumption is higher than that of any of the world's top 10 CO_2-emitting economies. As a result, even a small improvement in a country's energy efficiency can save a significant amount of energy. Using energy consumption data, an energy efficiency assessment can be made the concentration of carbon dioxide in the atmosphere (Liu et al., 2021).

4.2 Environmental Efficiency

CO_2 emissions can be seen in the results. Saudi Arabia has been in the top 10 CO_2-emitting countries for the past 5 years, from 2005 to 2017, the United Kingdom and South Korea have both made significant gains in efficiency, while Canada has remained efficient. Other market factors, such as growth in a country, changes in GDP, global economic trends, demographics, and climate patterns, can have a negative impact on energy efficiency. State that the European Union, for example, has made reducing energy intensity a central component of its climate change strategy in order to improve global energy efficiency. In the same way, organizations or countries set national and international goals for reducing energy intensity.

For the top ten CO_2 emitters, the efficiency of CO_2 emission is shown in **Table 7**. At 13,326 MMT of oil equivalent (MMT), global energy demand grew 1.82% in 2011 and reached 13,569 MMT in 2012. Following a small decrease (0.41%), the data from the following years show that the energy demand has continued to rise, as shown in **Figure 2**, even after this slight decrease.

In the long run, this leads to higher energy costs and inefficiency as a result of increased inefficiency, which, in turn, leads to higher government losses. As intended, subsidies are intended to help poor families, but they are often ineffective at helping wealthy families. Various countries have tried eliminating energy subsidies or instituting energy price reforms, with varying degrees of success. For policymakers, rigorous empirical analysis helps them understand and forecast the significance of energy subsidy reforms by analyzing energy efficiency's magnitude (level). To better understand how energy prices in the region are determined, this study examines the relationship between energy efficiency and energy subsidies. An example of this in 2018 is Haiti's effort to subside up to 2.2% of GDP for the country, which has been plagued by violence and political turmoil (Rao et al., 2022).

A similar pattern of fluctuating global CO_2 emissions has been observed, with emissions ranging from 33,049 MMT in 2011 to 33,579 MMT (a 1.6% increase) in 2012 to 33,049 MMT (a 1.72%) in 2013. The average CO_2 emissions of the top 10 CO_2-emitting countries from 2013 to 2017 are shown in the results. The CO_2 emissions intensity ranged from 0.637 to 0.0619, according to the study's findings. India is the top emitter of CO_2 among the world's top ten countries. While Saudi Arabia has the highest efficiency rating, it ranks 10th in terms of carbon dioxide emission intensity.

Table 8 lists the top ten countries in terms of CO_2 emission efficiency. Low-efficiency countries' CO_2 emissions could be reduced in 2017, according to the findings. Despite the fact that the United States, the world's largest source of carbon dioxide emissions, has the lowest potential for reducing those emissions, any increase in the efficacy of CO_2 emissions could have a significant impact on the environment.

4.3 Full Sample Analysis of Econometric Estimation

The values calculated using econometric estimation tools show that for the R&D fiscal cost, the OLS coefficient is 0.044, suggesting a statistically important and optimistic evaluation with a significance of over 5%. The OLS coefficient for fiscal expenditure for years of schooling, is 0.084, with a significance level of 1%. Fiscal decentralization is the method of moving

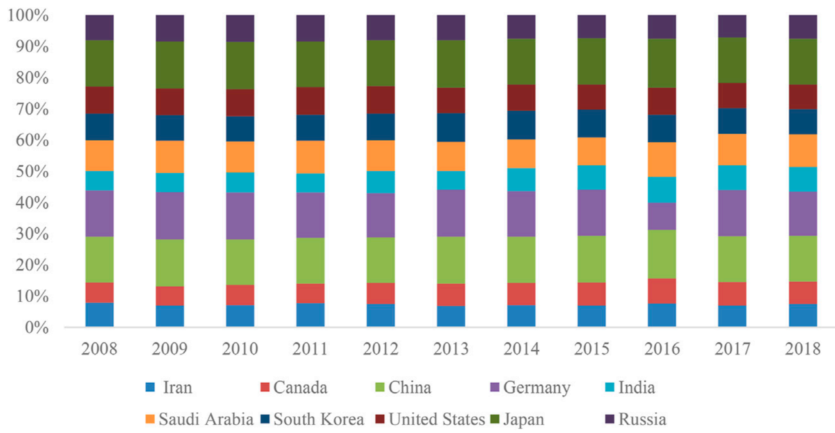

FIGURE 2 | Environmental efficiency score.

TABLE 8 | Ranking based on efficiency of CO_2 emission.

Country	CO_2 efficiency score	Ranking
Saudi Arabia	1.00	1
China	1.00	2
Japan	0.90	3
Iran	0.88	4
India	0.87	5
Germany	0.84	6
United States	0.75	7
Canada	0.73	8
South Korea	0.70	9
Russia	0.70	10

TABLE 9 | Estimation results of one- and two-step OLS.

	(1)	(2)	(3)	(4)
FS_lag1	0.2614***	0.2826***	0.2500***	0.1154***
	(0.0012)	(0.0016)	(0.0032)	0.0025)
GF	0.0276			
	(0.1651)			
GEP		0.0212**		
		(0.1126)		
GEP-lag			0.0201**	
			(0.0042)	
CO_2				0.0591***
				(0.0871)
PCR&D	0.0212	0.0250**	0.0281*	0.0211**
	(0.0011)	(0.0022)	(0.0207)	(0.0201)
FDI	0.0133	0.0260	–0.0201	0.0202
	(0.0011)	(0.0015)	(0.0134)	(0.0022)
URBAN	–0.2251	–0.2605	–0.1251	–0.1255
	(0.0115)	(0.0150)	(0.0621)	(0.0661)
GDPPC-lag	–0.0252*	–0.0211*	–0.0112**	–0.0128***
	(0.0016)	(0.0052)	(0.0048)	(0.0065)
Constant	1.0281***	1.0586***	1.1112***	1.1155***
	(0.1160)	(0.1225)	(0.0515)	(0.0501)
AR(1) test	–2.0622	–2.0711	–2.1115	–2.5212
	0.022	0.022	0.015	0.002
AR(2) test	–1.1551	–1.2251	–1.2670	–1.2001
	0.151	0.138	0.176	0.151
Sargan test	22.2555	14.5502	23.5612	17.5521
	0.067	0.066	0.21	0.135
Wald test	157,356	280,085	152,302	205,656
	[0]	[0]	[0]	[0]

control from the central government to local municipalities to promote macroeconomic productivity, growth, and long-term development. The theory behind decentralization is that public officials have more access to neighborhood expertise, which leads to less interjurisdictional competition and a closer alignment of local government interests and residents' prosperity. Any move to a green economy would require a switch to a low-carbon power system. According to the green growth campaign, the national accounting sector is restricted to sold goods, excluding environmental impacts that are undervalued. If the world is to avoid devastating climate change, the carbon intensity of industrial activity must be significantly reduced, a goal resoundingly accepted by the COP21 Paris agreement. Unfortunately, environmentally, sustainable innovations have not received adequate funding from Chinese businesses to satisfy the need for R&D expenses. According to numerous reports, China's R&D funding does not successfully encourage environmental academic achievements since the "vertical fund" is mostly used by government research agencies and universities. Countries face external and internal obstacles when implementing cleaner output, so the composition effect greatly outweighs the methodological effect.

The OLS estimation is shown in **Table 9**. Using the control variable, we can be confident that the findings meet the study's objectives. Coefficient values for the industrial system's negative impact on green economic development range from −0.324 to −0.374, −0.294 to −0.297. These effects are being caused by an increase in emissions from secondary industries as a result of the continued use of unsustainable energy sources (Shahbaz et al., 2020). The scale effect, which describes the impact on the environment of increasing government spending on public goods, is a factor in determining whether or not economic growth will be stimulated. Another possibility is that government spending on education will accelerate the shift from physical capital-intensive industries to human capital-intensive practices and thus reduce emissions and foster a new stage of economic growth. Investing in R&D also encourages the adoption of cleaner technology, such as environmental technologies and renewable energy, which improves resource quality during manufacturing and reduces the pollution-output ratio, also known as the technique impact. Government spending and interest rates are countercyclical in nature, according to the academic literature. Interest rates will rise during an economic downturn because it is difficult for businesses to obtain funds from the credit market while the stock market is constrained. Furthermore, the government is more likely to stimulate the economy through fiscal policy now than in previous years. At the end of the day, gross carbon emissions are linked to both production and other macroeconomic variables such as government spending (fiscal policy) and interest rates (monetary policy).

4.3.1 Green Economy Performance

Regardless of the methodology, the modified R-squared and significant coefficient model indicates adequate fitness. All OLS forecasts would have a negative and statistically significant impact on public spending if the significance level was set at 1%. It is safe to say that the green success metrics are somewhere in the −0.210 to −0.217 range. There will be an increase in the green economy and reduction in carbon pollution with a 1% increase in government green spending, if overall government spending remains the same. From −6.814 to −6.782, and from −0.567 to −0.583, are the AR(1) and AR(2) values for Arellano. The concentration of carbon dioxide in the atmosphere could be reduced by 10% with an increase in R&D spending of just one standard deviation. Because of this, it appears that changes in government finances have a substantial quantitative impact.

The ratio of gross consumption spending on GDP is used to measure government scale, and all three estimators that take into account the diverse characteristics of the regions have no substantial effects on pollutants. The degree of correlation between these results is concerned with the majority of carbon emissions, coal plants, and manufacturing operations. Since the central position has been partly or completely outlawed in gasoline since the mid-1980s, manufacturing operations account for a large portion of current lead concentrations. As a consequence, this report finds lead and carbon emissions to be air pollution. This means that the rate of green economic development is fluctuating. In other terms, higher green economic growth in the previous era appears to have a slower growth pace in the present period, but green economic growth will increase in the future (Hou et al., 2019). This is in keeping with the pattern illustrated. China's environmental regulations, for example, have the features of "1-year loosening and 1-year tightening." Local governments place a higher priority on GDP growth than environmental sustainability because GDP growth is closely associated with development through the hierarchical leadership ladder.

This pattern is referred to as a "judicial tournament," and it has culminated in unpredictable environmental policy as well as severe environmental concerns. About the fact that the central government has adopted several mandatory energy conservation and pollution control measures, the "judicial tournament" will continue for a while. As a result, the discontinuous environmental control may be used to describe the negative coefficient. As technology progresses, these countries' per capita GDP could grow dramatically. Technology can be a game-changer in terms of helping countries boost their green economic efficiency. Additionally, serial correlation and overidentifying constraint checks are used to ensure that our empirical estimates are accurate. Furthermore, the Sargan test, as well as Arellano and Bond tests, yield statistically negligible findings, indicating that instruments are not associated with residuals, and residuals lack second-order autocorrelation. **Table 10** shows the differences in energy efficiency.

The green economic efficiency index is shown in **Table 11**. In terms of structure and the technological impact, the countries with a low GDP per capita have comparable figures. The education spending coefficient is 0.215 in countries with a low GDP per capita, which is significant at a 1% level but drops to 0.049 in countries with a high GDP per capita, which is significant at a 5% level. The R&D per capita spending of low GDP per capita countries is projected to be 0.063. However, in countries with a high gross domestic product per capita, the PCR&D (per capita research and development) spending coefficient is 0.025, which is negligible at the 10% mark. The budget for education and R&D is impacted by the decelerating economy. In countries with varying GDP per capita, the divided study findings confirmed heterogeneous composition and technical impacts.

With the exception of the renewables' regulation, Climate Change Act 2008, and its determined emission targets, the most current of which is the fifth carbon budget (Salisu et al., 2020) for 2028–2032, promises the United Kingdom to divide emissions by 57% from 1990, may not have mattered. The command boosted the proportion of EU resources (not electricity) generated from sustainable sources from 12.5% to 20% by 2020. The EU was expected to have a 34% share of renewable energy resource (RES-E) by 2020, up from 24% in 2015, with 10% of the contingent (wind and solar). Unexpectedly, in contrast to its original position the United Kingdom Labour Government committed to one of the most difficult RES targets of 15% by 2020), agreeing to secure 40% of electricity from low-carbon sources and around 30% from renewables.

Regional policies of the central government, social tolerance for pollution, local bureaucracy productivity, and other unobserved regional exceptional factors can result in fiscal expenses for the green economy .The sum of money expended on schooling and science and advancement barely pollutes the climate. In terms of R&D spending and terms of total and share, Eastern China is the leader. The findings of the calculation show that the coefficients of fiscal expenditure on R&D are optimistic, with a significance level of 5% or greater for each observation. Additionally, to foster renewable energy technologies, investment in R&D has a huge effect on the daily capital. However, in

TABLE 10 | Differences in energy efficiency.

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: GEPI, green economic performance index.

TABLE 11 | Econometric estimate of green economic.

	(1)	(3)	(1)	(2)
FS_lag1	0.3613***	0.3833***	0.3301***	0.1133***
	(0.0011)	(0.0012)	(0.0032)	0.0032)
GF	0.0286			
	(0.1231)			
GEP		0.0213**		
		(0.1133)		
GEP-Llag			0.0301**	
			(0.0033)	
CO_3				0.0333***
				(0.0881)
PCR&D	0.0213	0.0230**	0.0231*	0.0301**
	(0.0011)	(0.0013)	(0.0303)	(0.0311)
FDI	0.0141	0.0160	−0.0403	0.0411
	(0.0011)	(0.0013)	(0.0133)	(0.0033)
URBAN	−0.2331	−0.2603	−0.1231	−0.1213
	(0.0113)	(0.0130)	(0.0631)	(0.0661)
GDPPC-lag	−0.0123*	−0.0111*	−0.0113**	−0.0138***
	(0.0016)	(0.0033)	(0.0038)	(0.0033)
Constant	1.0381***	1.0386***	1.1113***	1.1133***
	(0.1130)	(0.1113)	(0.0113)	(0.0101)
AR(1) test	−3.0633	−3.0811	−3.1113	−3.3313
	0.013	0.013	0.013	0.013
AR(3) test	−1.1331	−1.2331	−1.2380	−1.3001
	0.131	0.138	0.166	0.131
Sargan test	31.3333	13.3303	33.3613	18.3331
	0.068	0.063	0.11	0.133
Wald test	136,336	380,113	133,133	303,136
	[0]	[0]	[0]	[0]

contrast to countries with sufficient capital, such spending in restructuring the sector with updated technologies is marginal.

4.3.2 Research and Development Investment Structure Effect

According to the results, the area has a comparatively high compositional impact as opposed to the national average. R&D investments demonstrate a small improvement in the technological impact of −0.042 as compared to the full study findings of green economic efficiency. Also, in more industrialized nations, there are still powerful factors that can deadlock the shift from research funding to clean technology adoption. Clean technology adoption has been further slowed down by the current economic system and weak environmental laws, resulting in marginal technological consequences (Wohlfarth et al., 2020; (Palm and Backman 2020). Developing nations have the lowest capacity to offer higher education within the developing areas. Economic development dominates the region's environmental security, and the economic systematic transition to human capital-intensive industries could take decades. It is not the most advantageous location for high-tech investment. The findings for public expenditure on education were significant at the 5% stage, with a coefficient value of 0.04, and at the 10% stage, with a coefficient value of 0.035. Regardless of the dependent variables, the prediction outcomes for both of the analyses hit a 5% meaningful amount or better. **Table 12** shows the investment effect.

Second, since green innovation can improve economic growth, companies should stress green innovation's "converter" function, increase R&D investment, and promote the production of new green products and processes. Third, upper management influences the organizational environmental strategy, which has a direct effect on corporate environmental planning and culture (Cole et al., 2018).

4.4 Discussion

Consumption intensity has a direct impact on the effects of gas on the economy. Subsidy elimination on gas would reduce power production by less than 10%, but the gas would be replaced by another source of energy, such as oil for power generation. Because of the decline, the output of the gas sector drops by 15%–17%, depending on the revenue recycling scheme (Anser et al., 2020). It is estimated that in 2015, after-tax energy subsidies accounted for about $5.3 trillion, or 6.5% of the global GDP, while in emerging economies in Northern Africa Middle East and North Africa (MENA), the Middle East, and elsewhere, this percentage could range from 14% to 18% of the GDP (Khokhar et al., 2020a). Subsidies for fossil fuels, like the ones in this example, reduce the price of energy for consumers while increasing the revenue of energy providers. It is suggested that energy producers be given preferential treatment in this situation. Around $237 trillion (48%) of worldwide subsidies in 2012–2014, which is about 9% of the GDP of the constituency, is allocated to the MENA constituency.

Removed subsidies result in increased revenues or additional budget being transferred into the economy, which, in turn, promotes economic growth and corrects existing subsidy-related distortions. The economy's ability to grow and achieve positive outcomes is directly tied to the flow of new money into the economy. Extra revenues and savings (due to the removal of subsidies) could be cast off to fund energy investment, resulting in positive monetary effects (Iqbal et al., 2019a). Among the four reprocessing schemes, changing new revenue and the savings to households may yield the lowest economic welfare and government expenditures. Even though the primary focus of the existing studies is on the taxation of carbon emissions, these findings are consistent with those of Khokhar et al. (2020b) and Fu et al. (2021). Subsidy removal provides monetary benefits that can be best utilized through reorganization and investment, while tax cuts or investment is a more efficient way to allocate the savings from an efficiency point of view. Due to a reduction in excise tax or personal income tax, economic welfare has risen. Poor households pay a higher proportion of excise taxes, which means that cutting taxes does not help them financially. The manufacturing output decreased

TABLE 12 | Results of R&D investment effect.

	Low GDP per capita countries	High GDP per capita Countries	Full sample
L.log(R&D)	0.350***	0.392***	0.625***
	−0.099	−0.09	−0.046
PCGDP	0.039**	0.028***	0.025***
	−0.013	−0.015	−0.011
Constant	0.770**	0.898***	0.537***
	−0.283	−0.233	−0.232
Control variables	Yes	Yes	Yes
Arellano-bond AR(1)	−4.032	−4.427	−5.467
	[0.000]	[0.000]	[0.000]
Arellano-bond AR(2)	2.142	1.67	2.41
	[0.032]	[0.143]	[0.0152]
Sargan test	81.446	84.06	168.417

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

by 10%–11% (nourishment and other substances decreased by 7%, while crude oil fell 5%).

Energy subsidies are not going away with the emission reduction plan; they are just being removed or reduced in proportion to where they are going and who they are going to affect (Yu et al., 2021). Some of Iran's energy subsidies have been removed, while others have been kept in order to support manufacturing that relies on economic survival and has maintained a global antagonism, such as Saudi Arabia's oil production. In addition, they mainly used fuels that are cleaner than other energy sources among the underprivileged households. Among other things, energy subsidy reforms in Jordan now reserve Liquified Petroleum Gas (LPG) for low-carbon emission purposes (Asbahi et al., 2019).

In the policy and economic growth literature, there are two opposing views on the impact of environmental regulation on firm economic production. An organization's productivity and economic performance suffer as a result of the costs it incurs to comply with regulations, according to the traditional or cost-based perspective. According to this school of thought, profit-maximizing corporations would prefer sustainable engineering if it were profitable. As a result of this heterogeneity in effect composition, it is possible to show the extent of country variability. As a starting point, all resource-rich regions have a similar impact on government education spending and reinforcing the accumulation of human capital. These countries' education budgets are now higher, their educational systems are better, and their labor pools are better qualified as a result. When a region consumes more energy than it produces, R&D costs rise.

5 CONCLUSION AND POLICY RECOMMENDATIONS

A case study of the world's top ten CO_2 emitters was conducted using the DEA and OLS methods to develop a triple mandate approach to public spending, green finance, and zero-carbon mechanisms. Among the top ten countries that emit CO_2, China, Japan, and Saudi Arabia have been found to be the most energy efficient, while Russia has been found to be the least efficient from 2008 to 2018. Russia has a maximum energy intensity score of 0.409. Energy intensity may not be the best way to measure a country's energy efficiency when comparing energy intensity and energy efficiency. Two of the top ten CO_2 emitters, the United States and Saudi Arabia, have efficiency scores above 0.5, while the remaining countries have efficiency scores below 0.5, averaging 0.408. For the last 5 years, Saudi Arabia has held the top spot. However, the United Kingdom and South Korea have seen significant improvements in energy efficiency. Canada was efficient in terms of relative rankings. India's emission intensity is 0.637, while Saudi Arabia's CO_2 emission intensity is 0.462, based on the results of the study. Even though these countries have the lowest possible reductions in CO_2 emissions, an increase in the efficiency of CO_2 emissions could lead to significant reductions in carbon dioxide emissions. This could reduce emissions. It is a win–win situation when public spending and green finance work together to reduce emissions while still allowing for new types of economic development. This leads to higher efficiency while also being more environmentally friendly. To compensate for the costs of complying with the real world of dynamic rivalry, environmental legislation will produce technological advancements that partially, fully, or even more than completely compensate for those costs. Based on the assumption that green technology can lead to changes in manufacturing and operations at businesses, lowering output rates and increasing economic efficiency, the win–win outlook is premised.

1) To meet the national goal of non-fossil fuel power generation by 2020, the government must open up its energy market and implement an energy policy to increase the share of non-fossil fuel power generation to 34%. It is Saudi Arabia's priority to increase domestic energy sources, such as renewable energy, domestic oil, and gas, in order to reduce its dependence on imported energy. The rapid rise in international prices has had a significant impact on energy policy. Oil-based fuel subsidies have a significant impact on electricity generation. Keeping costs low is a top priority for businesses that use a lot of energy.
2) To remain globally competitive, some industries may be under more pressure to reduce operating costs than others. According to most economists, a high level of subsidies leads to excessive consumption and distorts the energy

market. However, reform may be stymied by the need to safeguard vulnerable groups, maintain political stability, and advocate on behalf of special interests. This research's policy implications were presented, and they can serve as a guide for departments in charge of developing strategies for improving efficiency measurement in light of energy economic and environmental efficiency.

3) An important benchmark for the development of renewable energy sources should be how closely consumption patterns align with CO_2 emissions, which is a function of both economics and the development model.
4) It is possible for a developing country to implement energy-saving business facilities such as power storage and energy conservation initiatives (see also **Section 2**). In order to increase carbon production, decision-makers need to maximize their response capacity to oil insufficiency, environmental conditions, and natural hazards. Oil imports could be reduced by improving energy quality, stable energy markets, and non-energy and supply replacement-related green energy sources.
5) To continue promoting renewable energy plans in regions, the government should improve information dissemination, optimize the integration of renewable energy, and increase the income-enhancing effect of renewable energy, which will create jobs.
6) The current supply and demand situation and the implementation of high taxes on fossil fuels should be developed to avoid the increasing demand for fossil fuels under the guidance of the supply-side energy reform policy.
7) Farmers' ability to allocate resources and the reform of traditional agricultural production methods, with petrochemical agriculture as the primary component, must be urgently improved.
8) It is imperative that emerging markets do everything they can to pave the way for the production of eco-friendly forms of energy. The efficient way to reduce energy-related CO_2 pollution and promote a green economy is, for example, to reduce the use of fossil fuels. In addition, limiting the use of fossil fuels allows for the development of low-carbon energy sources. Low-carbon resources have plenty of room because fossil fuels are constrained in their growth as a cost-effective strategy for reducing the environmental impact of energy generation, increasing energy production.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

MN: Manuscript, funding, data collection; methodology.

RETRACTED

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