Geoscience Frontiers 15 (2024) 101874

Contents lists available at ScienceDirect

Geoscience Frontiers

journal homepage: www.elsevier.com/locate/gsf

Research Paper

Does environmental policy stringency alter the natural resources-emissions nexus? Evidence from G-7 countries

Roni Bhowmik [a,b,c], Arshian Sharif [d,e,f,g,*], Ahsan Anwar [h,i], Qasim Raza Syed [j,k], Phan The Cong [l], Ngo Ngan Ha [l]

[a] School of Business, Guangdong University of Foreign Studies, Guangdong, People's Republic of China
[b] Faculty of Business & Entrepreneurship, Daffodil International University, Dhaka, Bangladesh
[c] Lancashire School of Buiness and Enterprise, University of Central Lancashire, Preston, United Kingdom
[d] Department of Economics and Finance, Sunway Business School, Sunway University, Subang Jaya, Malaysia
[e] Adnan Kassar School of Business, Lebanese American University, Beirut, Lebanon
[f] University of Economics and Human Sciences in Warsaw, Warsaw, Poland
[g] College of International Studies, Korea University, Seoul, South Korea
[h] Centre for Business Informatics and Industrial Management (CBIIM), UCSI Graduate Business School, UCSI University, Kuala Lumpur, Malaysia
[i] European University of Lefke, Lefke, Northern Cyprus, TR-10 Mersin, Turkiye
[j] Universiti Sains Malaysia, Malaysia
[k] Department of Business Administration, ILMA University, Karachi, Pakistan
[l] Faculty of Economics, Thuongmai University, Hanoi, Viet Nam

ARTICLE INFO

Article history:
Received 3 April 2023
Revised 21 March 2024
Accepted 22 May 2024
Available online 25 May 2024
Handling Editor: Dervis Kirikkaleli

Keywords:
Environmental policy stringency
Natural resources
CO_2 emissions
G-7 countries

ABSTRACT

Natural resource management is indispensable keeping in view their positive economic impacts as well as their detrimental environmental consequences. To achieve certain SDGs, it is inevitable to manage natural resources through effective policies that help to inhibit adverse environmental impacts. Based on this approach, the current empirical analysis aims to probe whether environmental policy stringency intensifies, meagres, and/or halts the abysmal environmental impact of natural resources in G-7 countries (United Kingdom, United States, Canada, Italy, France, Japan, and Germany) for the period from 1990 to 2020. To that end, we rely on the second-generation panel data approaches and panel quantile regression. The outcomes reveal that natural resources increase carbon dioxide emission whereas the synergy of natural resources and environmental policy stringency plunges emissions across the quantiles. These findings suggest adoption of a strict environmental policy for attaining the targets of SGD-08 (economic growth), SDG-09 (innovations), SDG-11 (sustainable cities), SDG-12 (responsible consumption of natural resources), and SDG-13 (climate action).

1. Introduction

The G7 countries, which include Canada, France, Germany, Italy, Japan, the UK, and the US, are among the most developed and industrialized nations in the world. These countries collectively account for a significant portion of global economic output, population, and carbon dioxide emission (CEM). According to world development indicators, the share of these countries in global GDP is almost 44% in 2021 (World Bank, 2023) (see Fig. 1). Next, almost 39% of the world population belongs to G7 countries (https://www.nationmaster.com/country-info/groups/Group-of-7-countries-(G7)). To meet the demand of millions of people, and to achieve and maintain voluminous output, G7 countries entail excessive energy. This is evident from the fact that G7 countries consume almost 30% of the world's energy (https://www.iea.org/news/g7-members-have-a-unique-opportunity-to-lead-the-world-towards-electricity-sectors-with-net-zero-emissions). Not only this, non-renewable energy consumption outstrips renewables in these countries, and, hence, G7 countries are accountable for almost 25% of global energy-based carbon emissions (https://www.iea.org/reports/achieving-net-zero-electricity-sectors-in-g7-members/executive-summary, see Fig. 2).

It is a reality that CEM contributes to climate change/environmental degradation/pollution. These environmental issues lead to

* Corresponding author at: Department of Economics and Finance, Sunway Business School, Sunway University, Subang Jaya, Malaysia.
E-mail address: arshian.aslam@gmail.com (A. Sharif).

https://doi.org/10.1016/j.gsf.2024.101874
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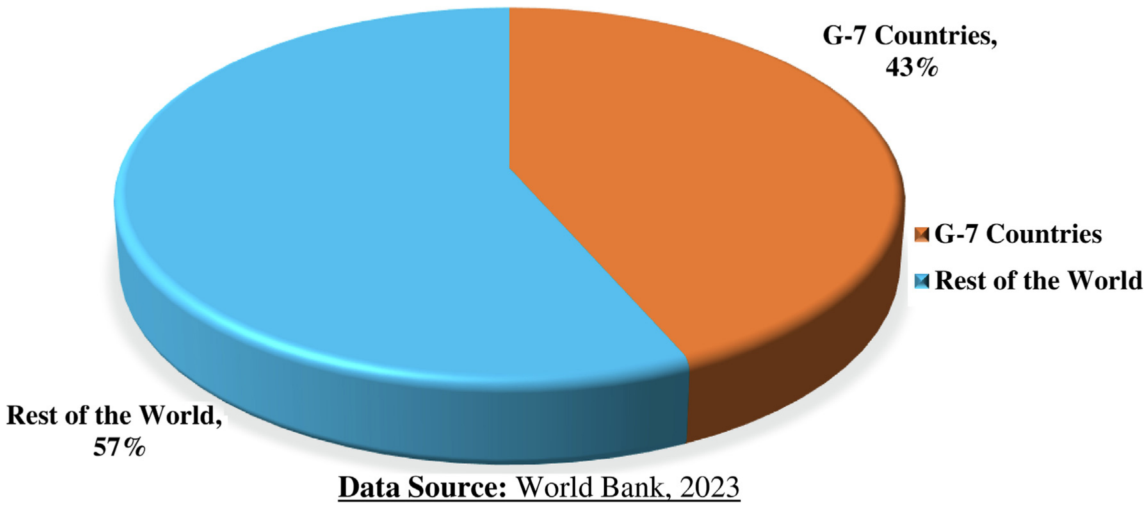

Fig. 1. Share of G-7 countries in global GDP.

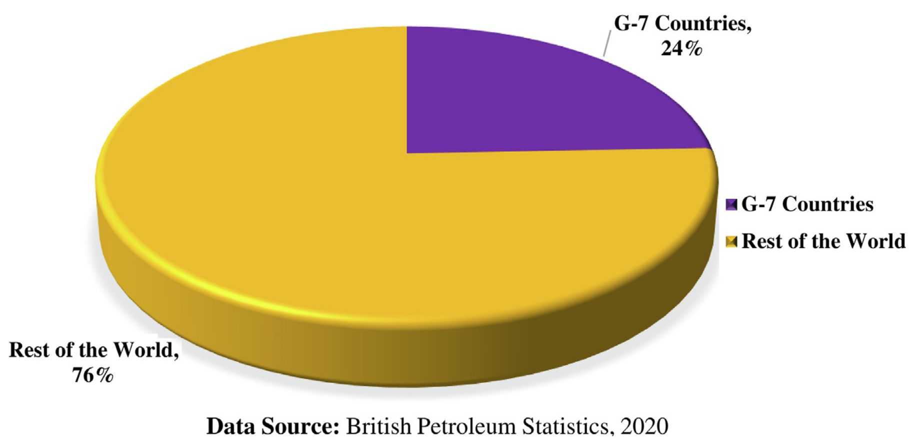

Fig. 2. Share of G-7 countries in global CO_2 emissions.

rising sea levels, extreme weather events, and biodiversity loss. Therefore, a huge economic and social loss is associated with emissions-induced climate change. The statistics claim that G7 countries will sacrifice 8.5% of their annual GDP due to environmental degradation in the absence of rigorous environmental policies (https://www.oxfam.org/en/press-releases/g7-economies-could-lose-85-year-2050-without-more-ambitious-climate-action-oxfam). Therefore, it is essential to restrict CEM to achieve carbon neutrality and net zero emissions. Although G7 countries work on collective efforts such as the Paris Agreement and COP26 to limit CEM, the volume of CEM is still at an alarming stage.

Hence, policymakers, researchers, and other stakeholders have been trying to mitigate CEM in G7 countries. To achieve net zero emissions and carbon neutrality, it is imperative to conduct research to identify the social and economic triggers of CEM. Wherefore, a plethora of research studies explore the push and pull elements of CEM. Focusing on the economic elements, existing literature guides that economic growth (Waheed et al., 2019; Liu et al., 2022), urbanization (Wang and Su, 2019), energy (Adebayo et al., 2022a), and technology (Sun et al., 2020; Zang et al., 2023) are critical drivers of CEM. Another vital trigger of CEM is natural resources (NRR). The prior literature argues that NRR has the potential to either surge or mitigate CEM. One class of researchers claims that exploration and extraction of NRR entail energy consumption, thus, CEM is expected to rise (Frankel, 2010). Moreover, NRR enhances economic growth, thereby CEM witnesses a rise (Usman et al., 2023). In addition to this, transportation and processing of natural resources are also pollution-intensive activities, leading to higher CEM. Not only this, over-reliance on natural resources discourages long-run investment in renewable energy. This in turn impedes renewable energy consumption and hence contributes to a high volume of CEM. Contrarily, the second class of researchers argues that revenue generated by NRR could be used to improve human capital, energy efficiency, and technological advancement. As a result, CEM is expected to decrease (Jahanger et al., 2022). Similarly, NRR leads to higher income that allows us to use renewable energy. In this way, NRR indirectly impedes CEM. Moreover, NRR can also be utilized for green projects and green jobs, thereby leading to lower emissions. NRR could also be used to develop sustainable cities and societies. This ultimately impedes CEM in an economy. Thus, the existing literature provides mixed outcomes on the NRR-CEM nexus. It is a point to note that the NRR-CEM puzzle should be solved to implement effective policies for achieving net zero emissions.

Another indispensable determinant of CEM is environmental policy stringency (EPS). It is worth reporting that EPS is the strictness of climate/environmental policies. It is believed that strict environmental policies/regulations result in improved environmental quality by mitigating CEM in an economy. An emerging body of relevant literature explores the relationship between EPS and CEM. In recent work, Yirong (2022) reports that EPS has an asymmetric impact on CEM. In particular, the study claims that EPS inhibits emissions. Albulescu et al. (2022) test the EPS-CEM nexus for 32 countries. The study reveals that EPS has a detrimental impact on CEM, especially on low-emitter economies. Ahmed and Ahmed (2018) also report the same conclusion for China. Similarly, Wang et al. (2020) highlight that EPS inhibits emissions in OECD countries. Hence, these studies highlight that EPS is an option to curb emissions. EPS imposes additional costs (in terms of taxation, etc.) on economic agents and restrain them from polluting the environment by consuming less amount of carbon-intensive products/services.

Parallel to this, one line of research on the NRR-CEM focuses on the synergy of NRR with another variable that has the potential to alter the NRR-CEM nexus. For instance, Adebayo et al. (2022b) point out that, although NRR enhances CEM, the combined effect of NRR and technology mitigates CEM. This implies that revenue from natural resources might improve the technology and hence CEM is experiencing a decline. In a recent study, Li et al. (2023) note that NRR escalates CEM in China in the absence of environmental policies, while the combined effect of NRR and environmental policies is negative, showing that natural resources in the presence of environmental policies curb CEM.

Hence, environmental policies can play an indispensable role to reshape the NRR-CEM nexus. There exist several theoretical reasons to explain how NRR behaves amidst environmental policies. For instance, strict environmental policies redirect natural resources' revenue toward innovation, research and development, improved energy efficiency, and human capital. As a result, CEM is expected to decline. Further, strong environmental policies propel to initiate green projects. To do this, NRR could be utilized for financing these projects, which ultimately curb emissions. In addition, strict environmental policies might impose some environmental standards and limitations on resource extraction industries, which, in turn, impedes CEM. EPS also demands for development of sustainable cities, contrarily, NRR could be used to finance these initiatives. Moreover, environmental policies (e.g., carbon tax and permits, etc.) might generate revenues from natural resources to replenish the environment. In addition to this, strict environmental policies compel NRR to be utilized for renewable energy adoption. Thus, we conclude that strict environmental policies impact the NRR-CEM relationship in two ways. First, environmental policies discourage the extraction and use of natural resources (the scale effect), which ultimately impedes CEM. Second, strict environmental policies divert the revenue of natural resources toward innovation, technology, and human capital, thereby CEM is expected to decrease (the technology effect).

It is a point to note that G7 countries also utilize a wide range of environmental policies to mend the environmental quality. Although the direct impact of environmental policies on CEM has been established, their impact on the NRR-CEM remains ignored. Hence, the objective of this study is to reinvestigate the impact of NRR on CEM while considering the role of environmental policies. Regarding the novelty of this study, this is among the earlier attempts to explore the NRR-CEM nexus amid environmental policies for G7 countries. Second, the existing literature on this line of research uses environmental regulation (i.e., voluntary actions taken by the public to curb environmental issues) as a proxy for environmental policies (see, for example, Li et al., 2023). This proxy is relatively weak since it does not cover the actions taken by the government to replenish environmental quality. Therefore, we adopt the environmental policy stringency (EPS) index of Kruse et al. (2022) as a proxy for strict environmental policies. It is worth reporting that the EPS index covers 13 environmental instruments to develop an index that can better portray the level of environmental policy stringency. Third, the present study utilizes the second-generation panel data methods to tackle cross-sectional dependence and heterogeneity. Fourth, we expand our analysis to examine the heterogeneous/separate impact of EPS on the NRR-CEM nexus in G7 countries with relatively high-, moderate-, and low-level emissions. For this purpose, we make use of the panel quantile regression (PQR) approach which is also immune to outliers and non-normal distribution of the dataset.

The remainder of the study is segregated into 5 sections. Section 2 covers the existing literature. We discuss the data, methodology and model in section 3. Empirical findings are reported in section 4. Finally, the conclusion and policy suggestions are reported in section 5.

2. Literature review

In a free market economy without constraints, those who pollute tend to shift the costs of their production to others, leading to excessive pollution (Pigou, 1920). However, it has been widely accepted that environmental degradation creates negative externalities that cannot be solved by market forces alone. As a result, it has become necessary for governments to implement strict environmental regulations to address the imminent threat to the ecosystem. The primary objective of environmental policies is to achieve environmental goals such as reducing CEM, which cannot be achieved by the free market (Taylor et al., 2012). Environmental quality is too critical to be left to market forces alone to solve problems such as pollution. Therefore, many governments have adopted various policy tools to minimize the harmful effects of environmental degradation, such as energy efficiency, green energy, and environmental tax (OECD, 2016). The stringency of environmental regulations is now being monitored by many countries using a standard measure such as the EPS index.

2.1. Environmental policy stringency and environment nexus

The Porter hypothesis proposes that EPS can encourage TEI and help businesses gain a competitive advantage through resource efficiency, pollution reduction, and the development of green products (Porter and Linde, 1995). This theory suggests that environmental regulations can stimulate TEI, leading to lower production costs, increased profits, and improved environmental performance. The environmental policy mix theory suggests that a combination of policy instruments, such as taxes, subsidies, regulations, and market-based mechanisms, can achieve better environmental outcomes than a single instrument alone (Fischer and Newell, 2008). This theory suggests that a mix of policy instruments can address market failures and encourage the adoption of environmentally friendly technologies.

Wolde-Rufael and Mulat-Weldemeskel (2021) investigated the impact of EPS on CEM in emerging countries (South Africa, Greece, Korea, Czech Republic, Poland, Hungary, and Turkey). They used the AMG method and found an inverted U-shaped link between EPS and CEM. Assamoi and Wang (2023) examined the collective influence of EPS and economic policy uncertainty (EPU) on CEM in the USA and China. They used NARDL approach and found valuable significant impacts of EPS in impeding CEM in both the USA and China. De Angelis et al. (2019) scrutinized the impact of GDP per capita and EPS on CEM in 32 economies. They confirmed an inverted U-shaped connection between EGR and CEM. The study also found that EPS played a strongly effective role in reducing CEM.

Albulescu et al. (2022) investigated how EPS affects CEM in 32 OECD countries from 1990 to 2015. Their study, which utilized the quantile fixed effect method revealed that EPS played a significant role in reducing CEM among countries with low carbon emissions. Wang et al. (2022) conducted a study to observe the impression of EPS and other macroeconomic factors on environmental quality in BRICS countries. They utilized a panel dataset and employed the CS-ARDL method. The empirical analysis confirmed that EPS and renewable energy play a supportive role in promoting environmental sustainability in BRICS economies. However, the study found that economic growth and industrial value-added were contributing factors to environmental pollution in these countries. Sun and Razzaq (2022) demonstrated that strong institutional policies and green innovation have a positive impact on environmental quality.

Wolde-Rufael and Weldemeskel (2020) focused on the nexus between EPS and CEM for BRIICTS countries. The study utilized the PMG-ARDL technique, which confirmed an inverted U-shaped linkage between EPS and CEM. The analysis demonstrated that EPS played a valuable role in dropping CEM, but only after a certain point. The study also found that the influence of renewable energy consumption was negative, while income and real oil prices had a positive linkage with carbon emissions. Chen et al. (2022) studied the potential effect of environmental tax and EPS on environmental quality in China. The study utilized a nonlinear ARDL method and found that EPS and environmental tax played a significant and supportive role in reducing emissions. Afshan et al. (2022) analyzed the influence of climate innovation, EPS, and renewable energy transition on environmental quality among OECD. The study applied the MMQR approach and found evidence of the EKC. The analysis demonstrated that EPS is a key determinant of environmental quality.

2.2. Natural resource and environment nexus

Chen et al. (2022) investigated the linkage of natural resource rent, green technology, GDP, and financial development with environmental quality. The study utilized a quantile ARDL method and found that GDP, financial development, and natural resource rent exert a positive influence on carbon emissions. Contrarily, green innovation found to have a significant carbon-lowering impact. Chien et al. (2023) investigated the linkage of renewable energy output, renewable energy consumption, population growth, and natural resource rent (NRR) with environmental degradation in China during the period 1991 to 2021. The study utilized a nonlinear ARDL method and found a negative linkage between NRR, renewable energy output, and renewable energy consumption with greenhouse gas (GHG) emissions. However, population growth and rapid industrialization had a positive impact on environmental quality in China. Awosusi et al. (2022) investigated the potential links between globalization, economic growth, NRR, renewable energy, and carbon emissions. They used FMOLS, DOLS, and ARDL models to examine the relationship between these variables. Their findings suggest that renewable energy consumption and globalization play a supportive role in maintaining environmental sustainability. The study also confirmed a causal relationship between NRR, EGR, and globalization toward CEM. Ahmed et al. (2020) applied bootstrap causality and Bayer and Hack cointegration tests to inspect the connection between human capital, EGR, NRR, urbanization, and ecological footprint in China from 1970 to 2016. They found a positive impact of NRR on ecological footprint, but URB and EGR were identified as factors increasing environmental degradation.

Additionally, the theory of the natural resource curse suggests that the availability of abundant natural resources can lead to environmental degradation due to a concentration of wealth and income in the hands of a few people, leading to corruption and poor governance (Sachs and Warner, 2001). This theory suggests that natural resource rents should be managed efficiently, and the benefits should be shared equitably to prevent environmental degradation. Sohag et al. (2021) inspected the validity of the EKC among 77 regions of the Russian Federation. Their findings, using the dynamic threshold regression method, confirmed the validity of the EKC, and the impact of energy price shocks was found to be supportive in reducing carbon emissions. Sadik-Zada and Ferrari (2020) evaluated the validity of the EKC and the pollution haven hypothesis (PHH) among 26 OECD economies. Using the PMG-ARDL method, they confirmed the presence of the PHH, indicating that a purely national perspective of the EKC is not satisfactory, at least for the global common pool resources context. Shaheen et al. (2022) conducted a study for China using techniques such as causality and impulse response functions to examine the impact of cleaner technologies on greenhouse gas emissions. Optimal resource management reduced emissions, while inadequate access to clean cooking technology and increased population density negatively impacted environmental sustainability. Sustainable regulations are necessary to address environmental issues.

Onifade et al. (2021) scrutinized the effects of economic globalization, urbanization, NRR, and human capital on environmental degradation in the E7 economies. The study used AMG, FMOLS, and DOLS to assess the link between the selected variables. Results showed that globalization negatively correlated with CEM, while EGR, URB, and NRR increased pollution. Wang et al. (2023) claimed that green technological innovation is also a useful tool for improving environmental quality. Gupta et al. (2022) examined the impression of TEI, NRR, and URB on environmental quality. They proved that URB reduces, while TEI and NRR increase the environmental quality. Xin et al. (2023) analyzed the influence of globalization, EGR, NRR, TEI, and URB on the environment of Asian nations. The findings revealed that natural resource utilization improved economic recovery while urbanization accelerated environmental deterioration.

3. Model and methodology

3.1. Model

To estimate the impact of economic and anthropogenic activities on environmental quality, the IPAT model (I for influence, P for population, A for affluence, and T for technology) has been used in several studies related to environmental economics. Nonetheless, IPAT has some shortcomings, e.g., its mathematical form is not conceivable. Moreover, the IPAT model is unable to evaluate the relative imperativeness of every independent indicator. To deal with these issues, Dietz and Rosa (1994) introduce a stochastic influence through the regression on population, affluence, and technology (STIRPAT) framework.

The general form of the STIRPAT model is as follows:

$$I_{it} = \varnothing P_{it}^{\beta_1} A_{it}^{\beta_2} T_{it}^{\beta_3} \varepsilon_{it} \tag{1}$$

In Eq. (1), CEM represents I (environmental impact), URB denotes P (urbanization), EGR is A (economic growth), and TEI represents T (technological innovations). Moreover, this study includes environmental policy stringency and natural resources rent in the model for probing their impact on environmental degradation. After adding these variables, the final form of the equation is as follows:

$$\mathrm{CEM}_{it} = \varnothing_{it} + \beta_1 \mathrm{EGR}_{it} + \beta_2 \mathrm{EPS}_{it} + \beta_3 \mathrm{NRR}_{it} + \beta_4 \mathrm{TEI}_{it} + \beta_5 \mathrm{URB}_{it} + \varepsilon_{it} \tag{2}$$

In Eq. (2), CEM represents CO_2 emissions. Next, EGR, EPS, NRR, TEI, and URB are economic growth (GDP), environmental policy stringency, natural resources, technology, and urbanization, respectively. Similarly, $\varnothing$ and ε show the intercept and error term, β_1 to β_5 are the coefficients of the STIRPAT model. Finally, i and t are present in cross-sections and period respectively.

Table 1
Data descriptions.

Variable	Sign	Measurement scale	Data Source
CO_2 emissions	CEM	Metric ton per capita	World Bank (2023)
Economic growth	EGR	GDP per capita (Constant US dollar, 2015)	World Bank (2023)
Environmental policy stringency	EPS	Market-based EPS index, ranging between 0–6	OECD (2023)
Natural resources rent	NRR	Rent of natural resource, percentage of GDP	World Bank (2023)
Technological innovations	TEI	Total number of patent applications (residents + non-residents)	World Bank (2023)
urbanization	URB	Percentage of population living in urban areas	World Bank (2023)

3.2. Methodology

The OLS regression models are based on the assumption that the dataset should follow the normal distribution, and there are no outliers in the dataset. Whereas, the real data of economic indicators show that the above-mentioned assumptions are not realistic (De Silva et al., 2016). Therefore, to address these issues as well as for providing a true picture of the results, Koenker and Bassett (1978) introduced a quantile regression technique. This approach has several superiorities over OLS regression, e.g., quantile regression does not develop any assumption about the distribution (Sherwood and Wang, 2016). Also, this technique has ability to deliver correct and robust outcomes in the presence of outliers (Bera et al., 2016). Moreover, Zhu et al. (2016) suggested that this approach does not consider any assumption regarding the occurrence of the moment function, and, hence, provides robust outcomes. These above-mentioned advantages of quantile regression insist to apply this approach in our study.

$$Q_{yi}(\varnothing_k|x_i) = x_i'\alpha_{\varnothing} \quad (3)$$

In Eq. (3), $\varnothing$ symbolizes the quantile, however, conditional quantile y_i in a given x_i. When we apply quantile regression in panel data, we face unobserved heterogeneity, which insists to apply panel quantile regression (PQR) with a fixed effect. The mathematical form of PQR is as follows:

$$Q_{yit}(\varnothing_k|\varphi_i, x_{it}) = \varphi_i + x_{it}'\alpha(\varnothing_k) \quad (4)$$

In Eq. (4), the φ_i is used for the fixed effect which also takes the parameter-related issues (Lancaster, 2000). Similarly, Koenker (2004) has introduced a new approach to provide robust outcomes in the case of infinite cross-sections. This approach presents a penalty term to address the issue of unobserved fixed effects. The following are the parameters of this approach.

$$\left(\hat{\alpha}(\varnothing_k,\eta),\{\varphi_i(\eta)\}_{i=1}^{N}\right) = argmin\sum_k^K\sum_t^T\sum_i^N\Omega_k\rho_{\varnothing_k}\left(y_{it}-\varphi_i-x_{it}'\alpha(\varnothing_k)\right)+\eta\sum_i^N|\varphi_i| \quad (5)$$

In the above equation, the sign of $\varnothing_k$ depicts quantile loss functions and k shows quantile, i and t symbolize country and time respectively. Furthermore, Ω_k signifies the relevant weightage, which allocates to the k-th quantile. Similarly, Ω_k also defines the role of different quantiles.

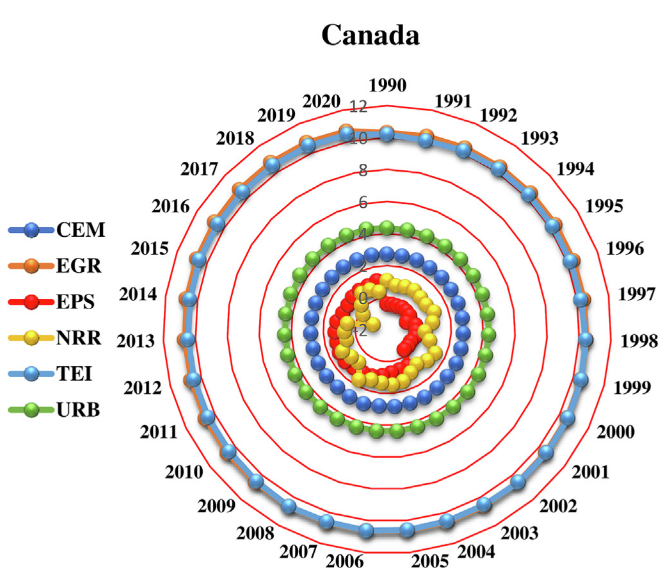

Fig. 3. Data trend of Canada.

3.3. Data

This study investigates the impact of EGR (Wang et al., 2024; Syed et al., 2024), EPS (Li et al., 2023), NRR (Jahanger et al., 2023), TEI (Durani et al., 2023) and URB on CEM for Group of Seven (G-7) countries (United Kingdom, United States, Canada, Italy, France, Japan, and Germany) over the period from 1990 to 2020. For this purpose, we collected the data of CEM, EGR, NRR, TEI, and URB from the World Development Indicators. Similarly, we gathered the data on EPS from the OECD database. The complete detail of the dataset is presented in Table 1. Whereas, the country-wise graphical representation of the dataset after taking natural logarithm is presented in Figs. 3–9 (data sources of these variables are presented in Table 1).

3.4. Descriptive statistics

The preliminary characteristics of the dataset are presented in Table 2. The mean values of CEM, EG, EPS, NRR, TEI, and URB are 2.265, 10.51, 0.747, −1.619, 10.85, and 4.353, respectively. Similarly, the maximum and minimum values of CEM, EG, EPS, NRR, TEI, and URB are 3.018, 11.01, 1.586, 1.610, 13.33, 4.519, and 1.495, 10.22, −0.693, −4.539, 8.699, 4.200, respectively. Descriptive statistics also show that the EPS and URB are negatively skewed, whereas remaining all the series are positively skewed.

Table 2 also presents the outcomes of the Jarque-Bera (J-B) test. The p-values of the J-B test are less than 0.05, which confirms that the data is not normally distributed and contains outliers. Similarly, as can be divulged from Fig. 10, all variables are distributed non-normally. This compels us to circumvent the mean-based methods. Therefore, we adopt the PQR approach that incorporates the entire distribution while estimating the slope coefficient (Syed et al., 2022; Caijuan et al., 2024).

4. Empirical outcomes

The study adopts a five-step procedure to report the findings. Initially, we use the cross-sectional dependence (CD) test, followed by the unit root tests. In the third step, we apply cointegration methods. Thereafter, we use the AMG estimator to probe the LR relationship among the considered indicators. In the last step

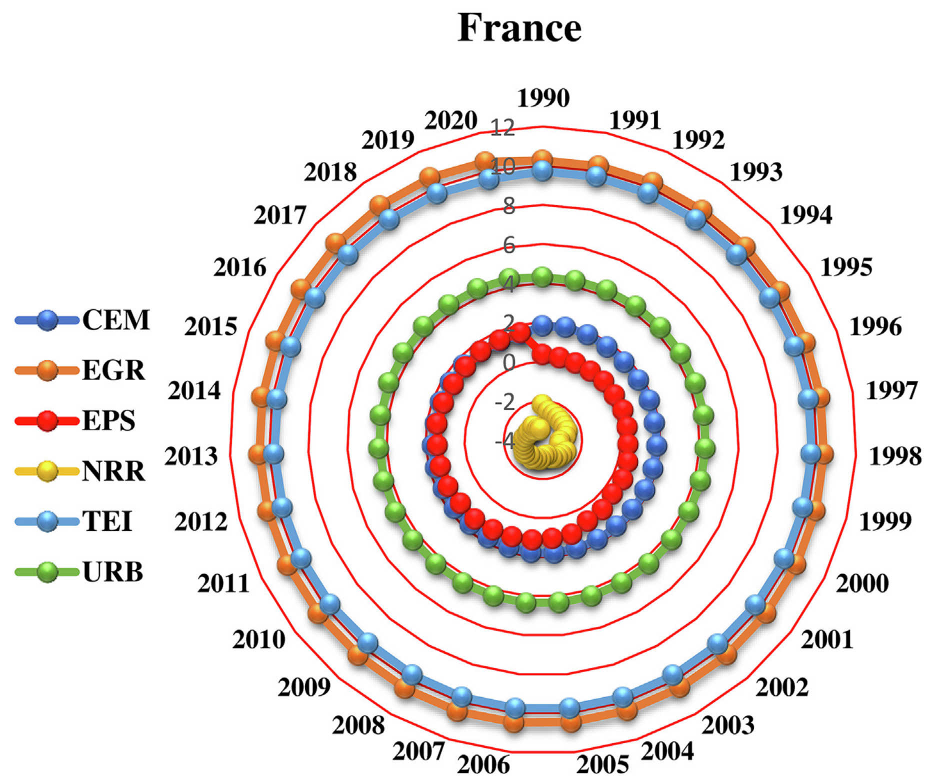

Fig. 4. Data trend of France.

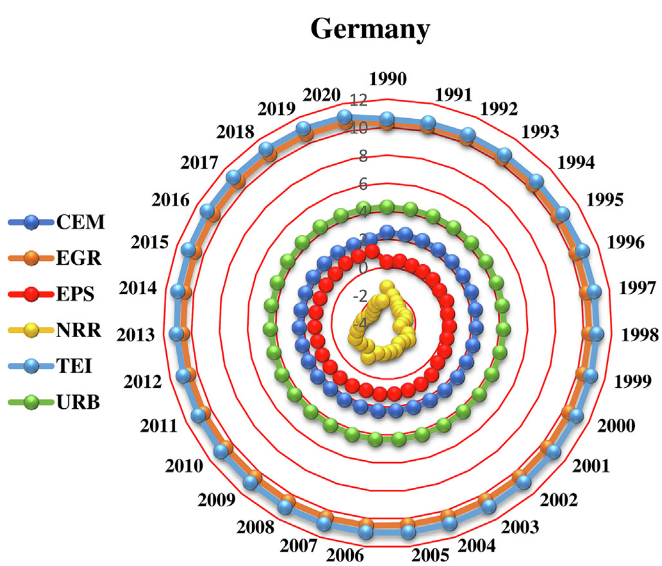

Fig. 5. Data trend of Germany.

(i.e., the fifth step), we use the PQR approach to explain the NRR-CE nexus amidst EPS across quantiles.

4.1. Testing CD

If a shock in one cross-section passes on to another cross-section, it is referred to as CD. The CD is a stern concern in the panel dataset whilst disregarding it might generate untrustworthy findings. Hence, we apply the CD test as reported in Table 3. As per the findings (see Table 3), CD remains in all variables. This compels us to use second-generation methods for robust outcomes.

4.2. Testing unit root

Evaluating the integration order (unit root) in the panel dataset is indispensable, especially if $T > N$. In our analysis, $T > N$, therefore, we investigate the order of integration using the unit root tests. In the panel dataset, there are two classes of unit root tests: the first-generation; and the second-generation unit root tests. It is a point to note that the first-generation tests ignore CD while the second-generation tests incorporate it. Hence, the latter method outshines the first-generation tests (Pesaran, 2007). Keeping in view the benefit of the second-generation tests, we employ the CIPS test and CADF test which are widely applicable second-generation tests. The outcomes from these aforementioned tests are reported in Table 4. From the CIPS test, it could be revealed that the entire dataset is integrated at I (1), except EPS. From the CADF test, it could be revealed that the entire dataset follows I (1), except CEM and EPS. Since none of the variables follow I (2), we move toward an appropriate cointegration testing procedure to discern whether there is any long-run comovement among the focused variables.

4.3. Testing cointegration

The empirical outcomes of Westerlund bootstrap panel cointegration test is presented in Table 5. The H_0 of the Westerlund cointegration test notes that there does not exist comovement among variables in the long-run, whereas the H_1 assumes vice versa. Since all statistics from the Westerlund test claim the rejection of H_0, we report that there is a cointegration in our case.

4.4. The long-run estimates

We adopt FMOLS and CS-ARDL approaches to probe the long-run impact of NRR, EPS, EGR, URB, and TEI on CEM.

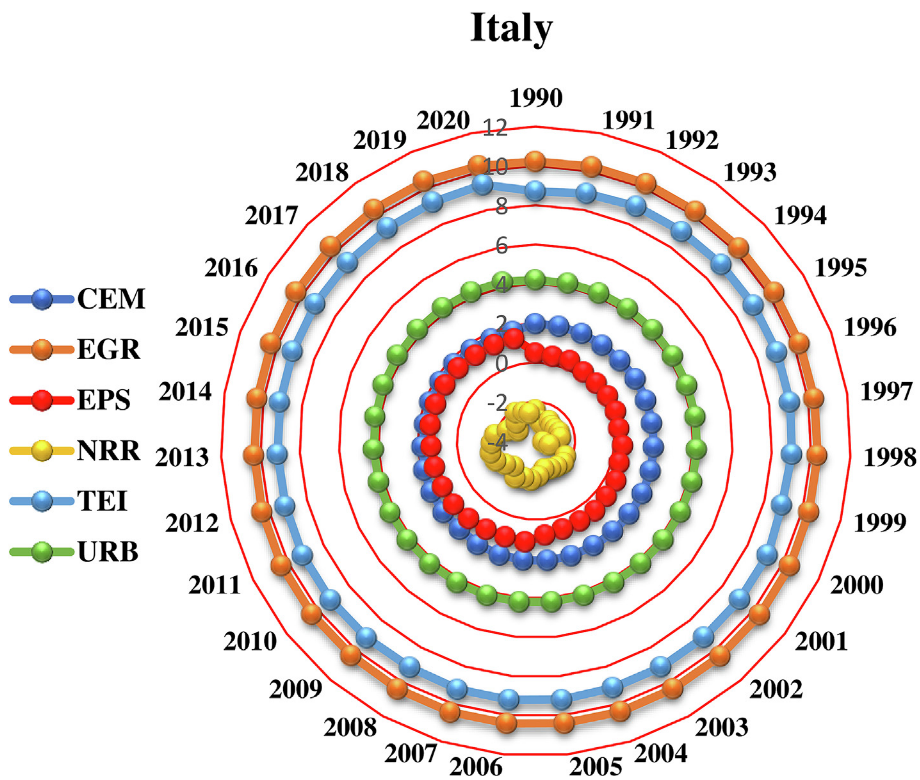

Fig. 6. Data trend of Italy.

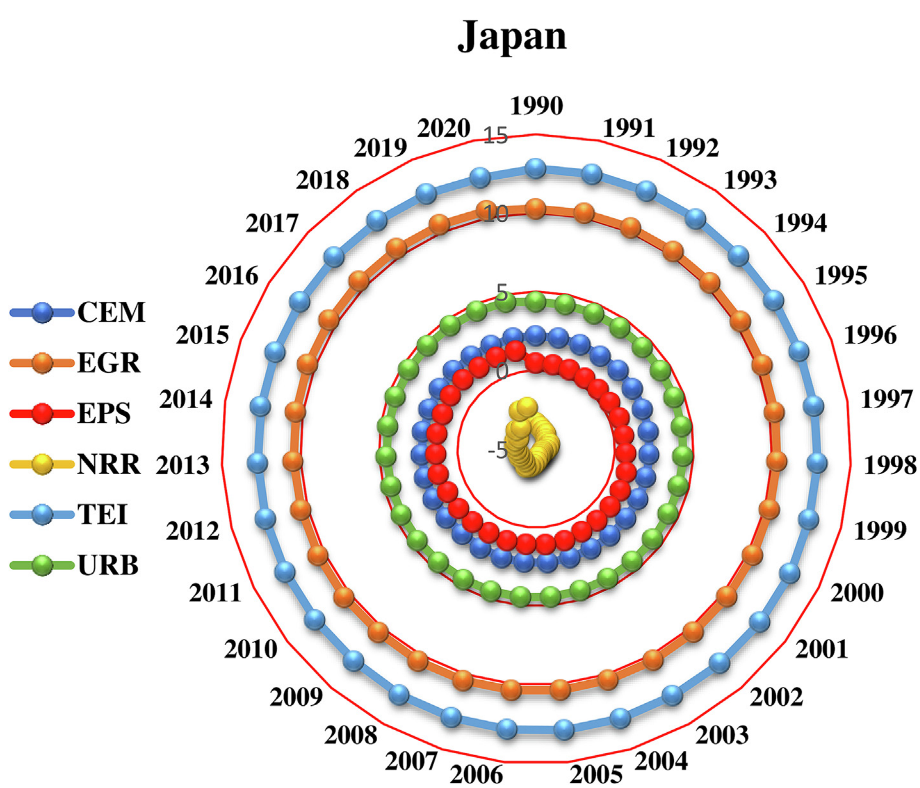

Fig. 7. Data trend of Japan.

From the outcomes of CS-ARDL in Table 6, it is reported that EGR, NRR, and URB have a positive relationship with CEM, indicating that these aforementioned indicators upsurge emissions in G7 countries. On the contrary, the coefficient of EPS and TEI is negative, inferring that strict environmental policies and technology inhibit emissions. Considering the outcomes from FMOLS, it is worth to report that EGR, NRR, and TEI increase emissions whilst EPS and URB plunge emissions in G7 countries.

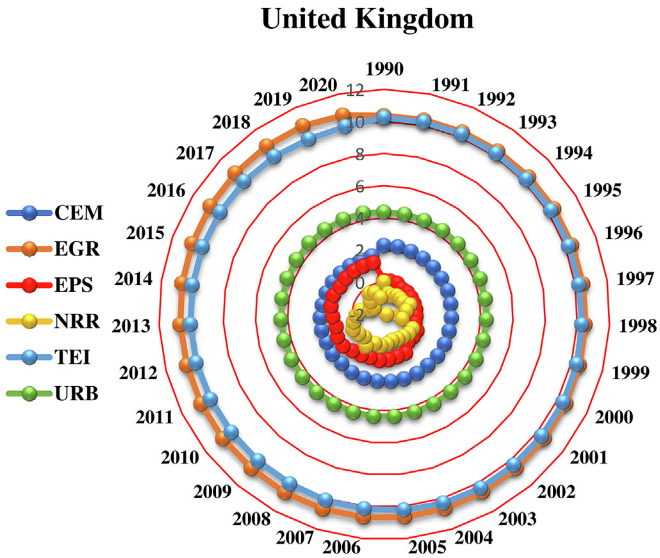

Fig. 8. Data trend of United Kingdom.

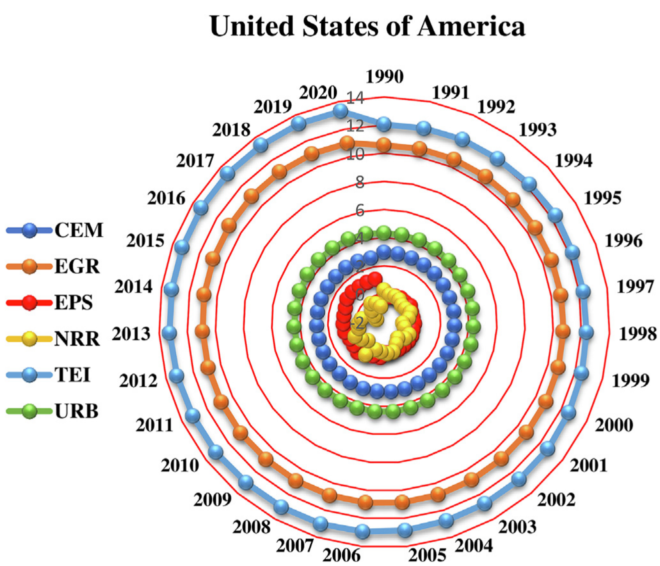

Fig. 9. Data trend of United States of America.

4.5. Findings from PQR model

This subsection is devoted to the findings from PQR model. We make use of 9 quantiles, ranging from the 10th to the 90th quantile, to capture almost the entire distribution. It is reported in Table 7 that EGR is statistically significant (henceforth SS) with a positive sign at all quantiles, except the 90th quantile. This divulges that CEM is fostered by economic growth. It is a well-documented point that a rise in income upsurges derived demand for energy and pollution-intensive goods, thereby CEM is expected to increase. The strength of the EGR-CEM relationship becomes meager while moving to higher quantiles. This indicates an interesting finding, i.e., countries with higher levels of CEM are becoming relatively clean as their growth upsurges. It could be possible since income in these countries improves energy efficiency and upgrades technology. These findings support the conclusion of Wei and Ullah (2022).

Next, NRR is positive and SS across the distribution of CEM, reporting that natural resources exacerbate environmental deterioration by enhancing CEM. Additionally, the coefficient of NRR becomes high as it moves to lower quantiles. This indicates that natural resources generate more pollution in low-emission G7 countries. The positive NRR-CEM relationship elucidates that revenue from natural resource extraction is not used to control CEM. Also, more and more natural resource extraction makes use of energy, thereby CEM is witnessing an increase. Moreover, NRR leads to higher EGR, which, in turn, escalates CEM. Not only this but NRR is also used to fund government projects and programs, which are not taking care of the environmental quality and use pollution-intensive energy sources and goods. As a result, CEM witnessed a profound increase. Our findings are in line with the conclusion of Gyamfi et al. (2022). It is evident that G7 countries keep extracting natural resources to meet their economic needs. Whereas, revenues from these resources are not effectively being utilized to replenish the environmental quality, leading to an enormous volume of CEM.

Regarding TEI, it is positive and SS across the entire distribution. This indicates that technology also enhances CEM in G7 countries. These outcomes are also reported by Raiser et al. (2017), Dauda et al. (2019), Salman et al. (2019), and Khattak et al. (2020). The coefficient of TEI becomes small as it moves from the 20th to the 90th quantile. This highlights that environmental-friendly technology (i.e., less CEM generating technology) is being used in low-emission G7 countries compared to high-emission G7 countries. These findings are possible due to an increase in production through technological innovation which might be heavily based on unsustainable energy (Khattak et al., 2020). It is also possible that this positive association between TEI and CEM is due to the scale effect, in which the increase in production leads to an increase in CEM.

It is a point to note that URB is SS at the 10th-60th quantiles with a negative sign. This infers that urbanization in G7 countries leads to low CEM. URB compels the use of renewables as modern cities/societies highly rely on solar and wind energy, thereby CEM is expected to decrease. These outcomes are supported by the findings from Zhu et al. (2018).

Table 2
Description statistics.

	CEM	EGR	EPS	NRR	TEI	URB
Mean	2.265	10.51	0.747	−1.619	10.85	4.353
Median	2.219	10.48	0.882	−2.003	10.475	4.360
Maximum	3.018	11.01	1.586	1.610	13.33	4.519
Minimum	1.495	10.22	−0.693	−4.539	8.699	4.200
Std. Dev.	0.414	0.183	0.509	1.631	1.361	0.071
Skewness	0.192	0.680	−0.545	0.149	0.493	−0.189
Kurtosis	2.011	2.759	2.334	1.855	1.890	3.484
Jarque-Bera	10.17	17.24	14.75	12.66	19.92	3.412
P-values	0.006	0.000	0.000	0.001	0.000	0.181
Observations	217	217	217	217	217	217

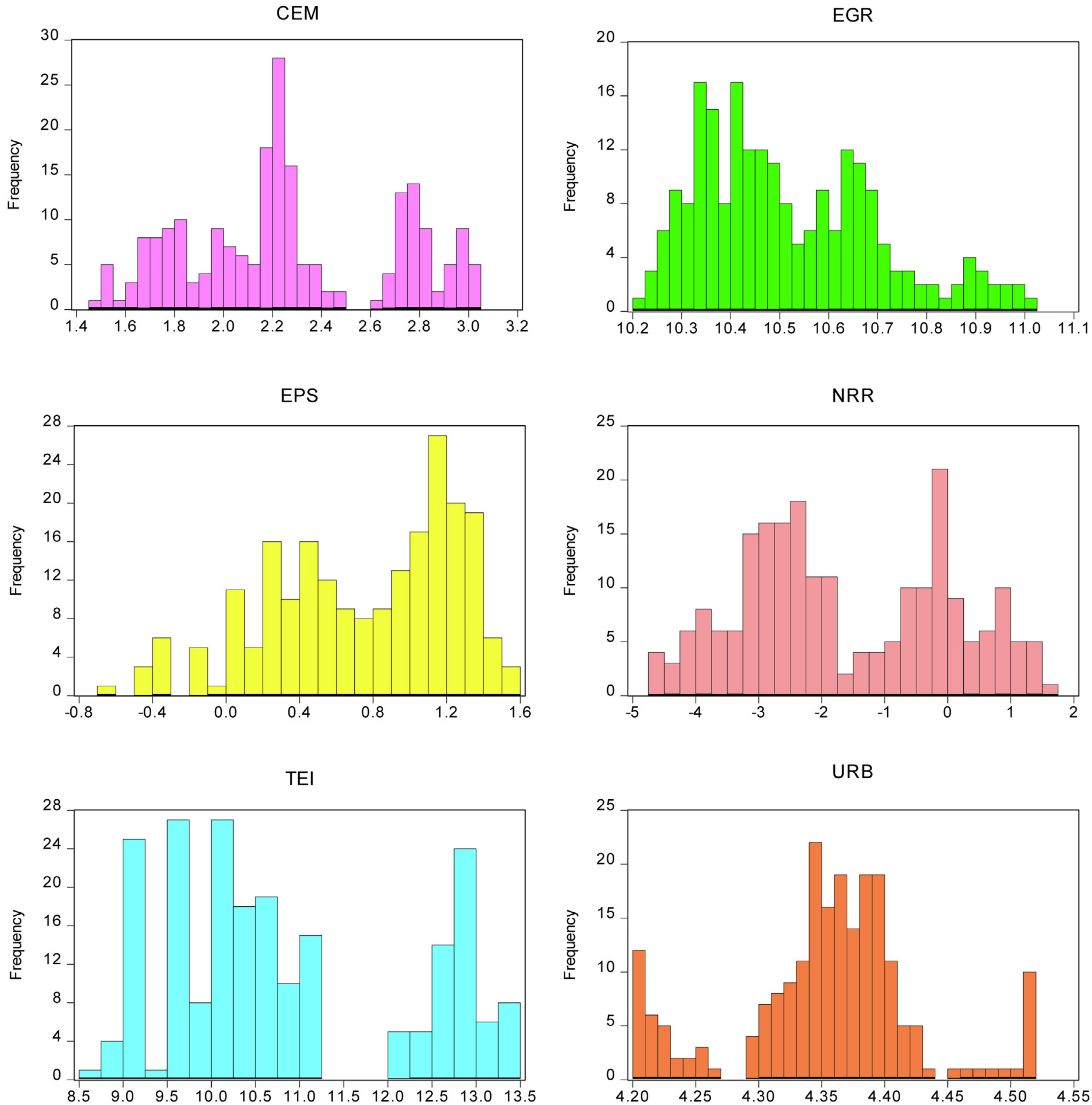

Fig. 10. Frequency distribution of the data.

Table 3
Results of cross-sectional dependence test.

Indicator	Test stat.
CEM	(13.456)***
EGR	(22.129)***
EPS	(23.549)***
NRR	(8.153) ***
TEI	(5.505) ***
URB	(23.912)***

(.) denotes t-stat. *** explains the level of sig. at 1%.

Parallel to this, NRR*EPS (interaction/combined effect of NRR and EPS) is negative and SS at all quantiles (except the 90th quantile) (see Fig. 11 also). This reports that although NRR enhances CEM, its impact amidst EPS is entirely different. That is, NRR plunges CEM amid EPS. It is worth noting that strict environmental regulations and policies propel the stakeholders to use the revenue generated from natural resource extraction to replenish environmental quality. For instance, G7 countries utilize environmental impact assessment to evaluate the possible damage from natural resources extraction and bind extraction companies/businesses to perform CSR activities to mend environmental quality. Not only this, in G7 countries, the natural resources extraction industry use license and permit to cause damage up to a certain level, and the revenue from these permits/license is utilized to replenish the environment. In addition to this, it might be possible that strict environmental policies turn NRR to clean technology, research and development, and investment in renewables. As a result, NRR leads to low CEM amidst EPS. These results are somehow in line with the findings of Li et al. (2023), who noted that natural resource dependence mitigates CEM in the presence of environmental regulations.

Fig. 12 depicts the comparison of the coefficients of panel quantile regression, CS-ARDL, and FMOLS.

Table 4
Results of cross-sectional augmented IPS and cross-sectional augmented ADF Unit Root Tests.

Indicator	CIPS test		CADF test	
	I[0]	I[1]	I[0]	I[1]
CEM	−2.090	−5.097***	−2.377**	–
EGR	−1.381	−4.079***	−1.334	−3.459***
EPS	−3.006***	–	−2.702***	–
NRR	−1.825	−5.888***	−1.248	−3.876***
TEI	−1.776	−4.459***	−1.725	−3.445***
URB	−1.142	−3.261***	−1.064	−4.038***

, and * show level of sig. at 5%, and 1%, respectively.

Table 5
Westerlund bootstrap panel cointegration test.

Westerlund (2007) bootstrap panel cointegration	
Gt	−2.472 ***
Ga	−8.334 ***
Pt	−5.882 ***
Pa	−8.526 ***

*** represents significant levels at 1%.

Table 6
Results of cross-sectional autoregressive distributed lag and fully modified ordinary least square tests.

Variables	CS-ARDL			FMOLS		
	Coeff.	St.Error	Prob.	Coeff.	St.Error	Prob.
EGR	**0.279*** **	0.395	0.480	**0.229*** **	0.024	0.000
EPS	**−0.999*** **	0.016	0.000	**−0.219*** **	0.008	0.000
NRR	**0.277*** **	0.010	0.006	**0.130*** **	0.002	0.000
TEI	**−0.176*** **	0.139	0.207	**0.187*** **	0.003	0.000
URB	**4.149*** **	0.060	0.020	**−0.413*** **	0.060	0.000

*** represents significant levels at 1%. Source: Author estimation.

5. Conclusion and policy implications

Natural resources are responsible for both economic growth and environmental deterioration. However, managing them through proper environmental policies could inhibit their environmental impacts. Based on this, we probe the impact of EPS and NRR on CEM while controlling EGR, TEI, and URB in the case of G7 countries. On top of this, we investigate the combined impact of NRR and EPS on CEM using PQR approach.

The dataset contains CD, which compels us to use the second-generation methods. The unit root tests note that the dataset is integrated at I(1), whereas the Westerlund cointegration test claims that there exists a long-run relationship between variables. Next, the CS-ARDL and FMOLS models reveal that EPS plunges CEM while NRR escalates it. Thereafter, the PQR approach reports that EGR, TEI, and NRR escalate emissions while URB curb it. Further, the combined impact of NRR and EPS reports that strict environmental policies manage natural resources in such a way that natural resources could curb emissions.

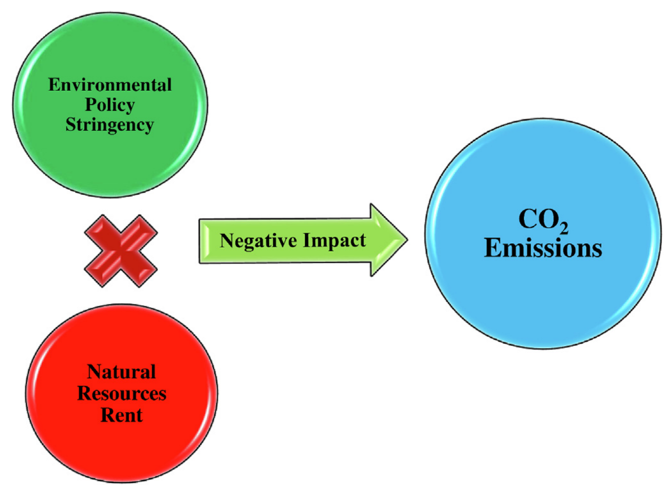

Fig. 11. Impact of interaction term of EPS and NRR on CO_2 emissions.

Table 7
Panel quantile regression results of interaction term of EPS and NRR.

Variables	Values	Grid of quantiles								
		0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
EGR	**Coeff.**	**0.654*** **	**0.455** **	**0.374*** **	**0.276*** **	**0.255*** **	**0.255*** **	**0.187*** **	**0.192* **	**0.135**
	St. Er.	0.095	0.183	0.033	0.022	0.037	0.030	0.068	0.097	0.428
	Prob.	0.000	0.013	0.000	0.000	0.000	0.000	0.006	0.050	0.752
EPS*NRR	**Coeff.**	**−0.258*** **	**−0.275*** **	**−0.238*** **	**−0.295*** **	**−0.282*** **	**−0.238*** **	**−0.154** **	**−0.121*** **	**−0.142**
	St. Er.	0.013	0.050	0.021	0.015	0.016	0.021	0.060	0.021	0.146
	Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.330
NRR	**Coeff.**	**0.323*** **	**0.356*** **	**0.334*** **	**0.390*** **	**0.390*** **	**0.358*** **	**0.301*** **	**0.277*** **	**0.300* **
	St. Er.	0.017	0.038	0.019	0.010	0.011	0.014	0.048	0.016	0.170
	Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.079
TEI	**Coeff.**	**0.181*** **	**0.194*** **	**0.194*** **	**0.192*** **	**0.183*** **	**0.176*** **	**0.164*** **	**0.150*** **	**0.128*** **
	St. Er.	0.004	0.012	0.006	0.005	0.008	0.005	0.008	0.029	0.025
	Prob.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
URB	**Coeff.**	**−1.494*** **	**−1.023** **	**−0.819*** **	**−0.553*** **	**−0.465*** **	**−0.441*** **	**−0.236**	**−0.203**	**0.006**
	St. Er.	0.225	0.410	0.071	0.047	0.104	0.083	0.167	0.303	1.122
	Prob.	0.000	0.013	0.000	0.000	0.000	0.000	0.159	0.503	0.995

Source: Author's estimation. ***, ** and * represent significant level at 1%, 5% and 10%, respectively.

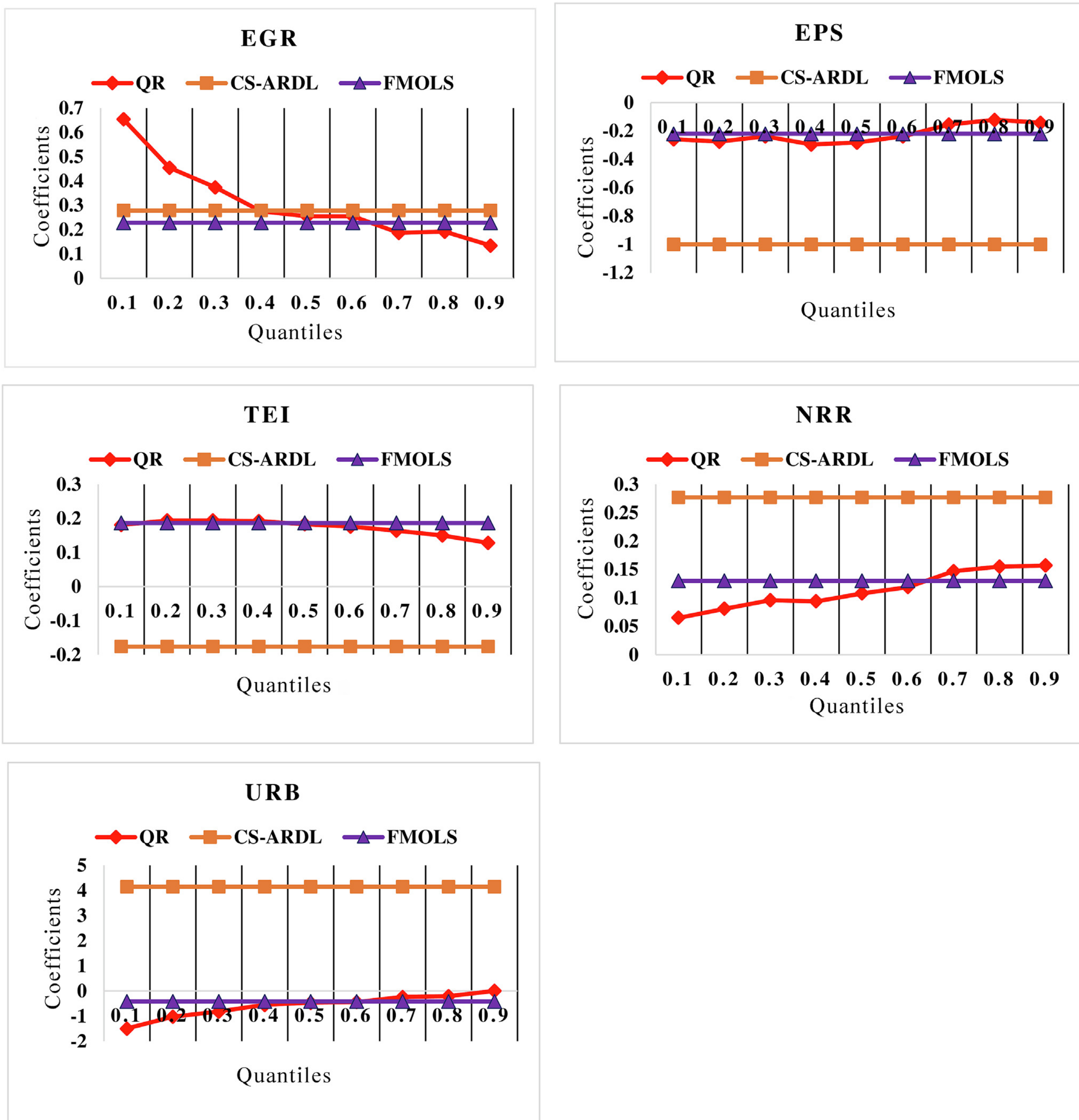

Fig. 12. Coefficient plots of linear and quantile regression.

These findings suggest various policy directions for attaining the targets of SGD-08 (economic growth), SDG-09 (innovations), SDG-11 (sustainable cities), SDG-12 (responsible consumption of natural resources), and SDG-13 (climate action). The positive impact of TEI on CEM calls for special attention to improve technology in such a way that it could increase production without deteriorating the environment. The negative impact of URB on CEM suggests policymakers to enhance URB in G7 countries. This could upsurge human capital and renewable energy utilization, thereby CEM is expected to decrease. The positive EGR-CEM relationship suggests adopting those determinants of EGR which do not lead to environmental degradation. For instance, renewable energy consumption and human capital could be the sustainable drivers of EGR, and these indicators need to be increased to improve economic growth. Finally, we propose to adopt strict environmental policies to curb the environmental impacts of NRR. To that end, carbon taxation and trading schemes should be initiated for the natural resources extraction industry. Next, strict measures need to be taken to upsurge the proportion of renewables in the energy mix. Taxes on renewables (e.g., feed-in tariff) should be strictly reduced. The penalties on violation of environmental regulations/laws/rules should be increased to restrict all stakeholders from generating more and more emissions. Finally, environmental policies should be designed in such a manner that resources rent could be passed on towards investment in energy efficiency, human capital, and climate change mitigation technologies, among others.

With regard to the limitations of this study, we ignore the dynamic quantile regression approach in this study, which future studies could cover. In addition, the structural breaks are also ignored in this empirical analysis, hence, future studies might handle structural breaks to get more and more robust outcomes. Also, the asymmetric impact of regressors is disregarded in our analysis. The subsequent studies should also adopt asymmetric analysis to explore whether positive and negative shocks in regressors have a heterogeneous impact on CEM.

CRediT authorship contribution statement

Roni Bhowmik: Data curation, Writing – original draft. **Arshian Sharif:** Formal analysis, Investigation, Supervision, Writing – original draft. **Ahsan Anwar:** Conceptualization, Project administration, Supervision, Writing – review & editing. **Qasim Raza Syed:** Conceptualization, Investigation, Methodology, Project administration, Writing – original draft. **Phan The Cong:** Data curation, Writing – original draft. **Ha Ngo Ngan:** Data curation, Software, Writing – original draft.

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.

Acknowledgements

The funding source for this research are as follows: (1) Guangdong University of Foreign Studies, Guangdong, China (Grant No. 299-GK23G396). (2) This research is funded by Thoungmai University, Hanoi, Vietnam.

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