A Path to Carbon Neutrality: Do Environmental Tax, Green Technologies and Natural Resources Extraction Matter for Environmental Sustainability?

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Abstract

BRICS countries (Brazil, Russia, China and South Africa) and G-7 countries (Japan, USA, France, UK, Canada, Italy and Germany) have experienced high economic growth while polluting their environment. This study explores how environmental sustainability of these countries can be achieved via environmental technology and renewable energy use. It also shows the uncertainty of environmental tax and natural resources extraction in reducing carbon emissions (i.e. CO_2). Unlike previous studies using conventional econometric analysis, we employ novel Bayesian panel regression to analyze data spanning from 1996 to 2021 for twelve countries within the G-7 and BRICS cohorts. The results of Bayesian regression are further verified by using the method of moment quantile regression (MM_QR). The results show that extraction of natural resources (i.e. forest rents, natural gas rents and fossil fuels) and economic growth, contribute to an increase in carbon emissions across these countries. We also observed that implementation of green environmental technology and uptake of renewable energy reduce carbon emissions within these countries. The results further show the uncertainty of environmental tax and other natural resource extraction (i.e. coal rents, oil rents, mineral rents) on minimizing carbon emissions. The study addresses two policy interventions: first, to promote renewable energy and technological innovation in the environmental sector to achieve carbon neutrality. Second, to reduce the effect of natural resource extraction, such as forest and natural gas rents, on increasing carbon emissions. The study offers actionable insights for policymakers in other developing countries to balance economic growth and natural resources extraction with environmental sustainability.

Keywords: Environmental technology; environmental taxation; natural resource extraction

JEL Classification Codes: Q56,Q55,C53,C63

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1. Introduction

It is well documented that the economies of the BRICS countries (Brazil, Russia, India, China and South Africa) and the G7 countries (Japan, USA, France, UK, Canada, Italy, Germany) continue to grow over time (Ullah et al., 2023; Rehan et al., 2025). Due to large populations and higher demand for energy to meet market consumption, these countries use more natural resources such as oil, natural gas, minerals, coal and forests to expand their economic development (Huang, 2024; Jia et al., 2024; Irfan et al., 2025). By extracting natural resources, these countries generate income through rents to improve their economic status and ensure better living standards for their citizens. However, this race for economic prosperity and over-use of natural resources has inadvertently come at a high environmental cost, evident in the significant increase in environmental degradation such as greenhouse gas (GHG) emissions, which are the primary cause of global climate change (Zhou et al., 2024; Irfan et al., 2025).

Among the various contributors, the economies of the BRICS countries and the G-7 stand out with significant impact on both global economy and resulting in excessive carbon dioxide emissions causing atmospheric pollution (Luo & Kamarudin, 2024; Irfan et al., 2025). Therefore, both the BRICS and the G-7 countries face the major challenge of dealing with large amounts of carbon dioxide emissions. For example, the BRICS and G-7 countries are responsible for 45% and 22% of total carbon dioxide emissions in 2020, respectively (Luo &Kamarudin, 2024). These countries' higher carbon dioxide emissions are also due to rapid industrialization and urbanization, which are at the forefront of global energy consumption and industrial emissions. Their dual roles as economic leaders and major polluters place them in a unique position of responsibility that requires adopting environmental policies that balance economic growth, natural resources extraction and environmental protection.

In this regard, environmental taxes and technologies are important to combat climate change by reducing carbon dioxide emissions and improving environmental sustainability in these countries. For example, an environmental tax has been introduced to ensure that carbon neutrality reaches zero in 2050 and switched to the use of clean energy to improve environmental sustainability and achieve Sustainable Development Goals 7 and 13 (Hao et al., 2021; Jahanger et al., 2024; Kartal, 2024; Byaro and Timbuka, 2025). On the other hand, we also believe that the adoption of environmental technologies in both the G7 and BRICS countries could play a crucial role in addressing environmental challenges, promoting sustainable development and reducing harmful emissions (Manjang et al., 2023b; Onwe et al., 2023; Cao et al., 2025).

It is in this context that the relationship between economic development, environment technology, resource extraction and environmental sustainability is the subject of intense debate and scholarly interest, particularly when examining the collective influence of the BRICS and G-7 countries, as these countries represent a wide range of economic systems, stages of development, and policy approaches to environmental issues. Their economic activities, particularly in energy-intensive sectors such as manufacturing, mining and transportation, are major contributors to the world's total greenhouse gas emissions (Jahanger et al., 2024; Wang et al., 2022). Furthermore, their large population and high consumer demand exacerbate pressure on natural resources, leading to increased manufacturing and transportation activities and a resulting increase in energy consumption and emissions (Jahanger et al., 2024).

Given these environmental challenges within the G-7 and BRICS countries, policymakers are exploring various tools to steer these countries toward a more sustainable development path.

Carbon taxation is proving to be one of the most discussed policy levers, aiming not only to reduce carbon emissions but also to encourage the adoption of clean technologies and the transition to renewable energy sources. Environmental taxes are increasingly recognized as effective legislative tools that can significantly reduce carbon emissions and address the pressing issue of climate change(Ullah et al., 2025). However, questions remain regarding the true effectiveness and broader economic and social impact of such measures, particularly when applied in the different contexts of BRICS and G-7 countries.

The current study aims to investigate deeper into the dynamics between resource extraction, environmental policy, technological innovation, energy transition, economic growth and carbon (CO_2) emissions. We focus on the potential of the BRICS and G-7 economies to pursue sustainable development without sacrificing their economic ambitions. BRICS and G7 countries have been studied separately through the impact of environmental taxes, natural resources extraction, and the relationship between carbon emissions and environmental technology. In this view, there are limited studies combining these countries and filling the gap in the existing literature. The focus of this research is to examine how these influential economies can use policy tools such as environmental taxes and support for green technologies to achieve a viable balance between economic, natural resources and environmental goals.

The contributions of this study are fourfold. First, it complements the existing body of knowledge by providing a more clear understanding of how environmental policies (e.g. carbon tax) influence the development of economic growth and environmental protection in the BRICS and G-7 countries. In practice, the results are intended to provide policymakers and key stakeholders with data-driven insights into the consequences of environmental policy decisions. Second, it contributes to the literature on the role of green technologies and taxes in curbing emissions and supporting sustainable development, and what outcomes will be crucial in shaping future policies and strategic initiatives at both national and international levels.

Third, unlike other studies (Amin etal., 2025; Qianqian et al., 2025; Raihan, 2023; Khan & Hassan, 2024; Shahbaz et al., 2024; Zhou et al., 2024; Jia et al., 2024; Zhang & Zheng, 2023; Kwilinski et al., 2024; Shahbaz et al., 2024) that uses conventional frequentist regression such as autoregressive distributed lag(ARDL), generalized method of moment (GMM), fully modified least squares (FMOLS), cross-sectional autoregressive distributed lag (CS-ARDL), panel correct standard error (PCSE), pool mean group (PMG), our study uses a novel Bayesian panel regression technique, to examine the impacts of environmental taxes, renewable energy, economic growth, natural resources (e.g., coal, mineral, oil, forest, and natural gas rents), and green technology (i.e. environmental technology) on carbon emissions from 1996 to 2021. The main advantage of using Bayesian panel regression is that it provides the ability to report results in mean or median forms, and it uses prior and data evidence/likelihoods to produce posterior distribution. Another advantage of Bayesian modelling is that it can be used regardless of the sample size and it applies Markov Chain Monte Carlo Simulations (MCMC) and convergence chains to assess the general equilibrium stationarity of parameters (Byaro et al., 2024).

Fourth, another novel contribution is the construction of the index of natural resource rents (i.e., coal, natural gas, forest, minerals, and oil) using principal component analysis (PCA) to test the robustness of the results using quantile regression. It is also important to note that previous studies have limited the combined role of green technology and environmental taxes on carbon emissions, leaving a gap in current academic discourse.

Our main research questions are: (i) How effective are environmental taxes in reducing carbon emissions in the G-7 and BRICS countries? (ii) Do environmental technologies and natural resource extraction reduce carbon emissions in these countries?

The rest of the study is structured as follows. Section two highlights the theoretical and empirical literature, section three provides the data sources and methodology, section four presents the results, and section five discusses the results. The final section contains conclusions and policy implications.

2. Theoretical literature

This study is based on several major environmental and economic theories. The Kuznets curve was originally introduced in the 1950s to show the relationship between economic growth and income inequality (Kuznets, 1955). Then it was extended to the environmental hypothesis known as Environmental Kuznets Curve (Grossman & Krueger, 1991).The hypothesis explains that environmental quality may decrease during periods of economic development due to an increase in industrialization, energy consumption and urbanization, leading to depletion of natural resources, which in turn leads to climate change. This means that the increasing extraction of natural resources and the production of goods and services also results in higher carbon (CO_2) emissions.

On the other hand, there is a Resource Rent Curse (RRC) theory that highlights the possible negative consequences of a heavy reliance on natural resource extraction, particularly relevant to coal, mineral and oil rents leading to CO_2 emissions (Auty, 2002). Increasing natural resource extraction in turn leads to higher economic growth and investment, which leads to CO_2 emissions (Jia et al., 2024). It is also worth noting that the literature on innovation and diffusion theory includes technological innovation as an important CO_2 reduction tool (Rogers, 1962). Furthermore, the Porter hypothesis emphasizes the role of environmental regulations in stimulating innovation and technological development, leading to improved economic performance (Porter & Linde, 1995). Environmental taxes are also important to reduce pollution such as CO_2 and promote the adoption of investments in clean technologies (Kafeel et al., 2023; Zhong et al., 2024). All of these theoretical foundations provide a clear basis for explaining the relationships between natural resource extraction, environmental taxes and technology and their influence on carbon emissions.

2.1 Empirical literature

In Table 1, we summarize the empirical literature related to natural resource extraction, environmental technology and taxation, and carbon (CO_2) emissions from different countries. Many studies support the assumption that economic growth increases CO_2 emissions (Cao et al., 2022; Chen et al., 2023; Khan et al., 2021; Pradhan et al., 2024; Raihan, 2023; Raihan &Tuspekova, 2022). This means, that as the economy grows, it leads to higher energy consumption and industrial production (Pradhan et al., 2024). Some literature also shows that natural resource rental impacts CO_2 emissions. For example, fossil energy consumption increases CO_2 emissions(Raihan et al., 2023; Wang & Yang, 2024). Likewise, rents from natural resources such as gas, coal, oil, forests and minerals affect environmental quality by polluting CO_2 emissions in BRICS countries (Jia et al., 2024; Zhou et al., 2024). This view is also supported by Rehman et al. (2024) that coal rents continuously increase CO_2 emissions. Similarly, many studies show that natural resource rents worsens environmental quality and increases CO_2 emissions (Chen & Chen, 2024;Khan& Hassan, 2024; Shahbaz et al., 2024; Shang et al., 2024; Voumik et al., 2023; Wang et al., 2024; Yu-Ke et al., 2022).

Table 1 also summarizes the impact of environmental taxes on carbon (CO_2) emissions. It shows environmental taxes play a crucial role in improving environmental sustainability (Ibe et al., 2024; Xu et al., 2023; Zhang & Zheng, 2023; Zhong et al., 2024). The environmental tax is a great tool to reduce environmental pollution and motivate society in various countries to continue using clean energy sources (He et al., 2023; Wolde-Rufael & Mulat-weldemeskel, 2023; Xu et al., 2023). Although environmental taxes are effective in reducing CO_2 emissions, the effectiveness of tax policy varies depending on country and tax design (Kafeel et al., 2023). For example, if the tax rate is lower than expected, it may hinder the adoption of green technologies. Literature have shown that environmental protection tax reduce carbon intensity and improve green innovation in China (Zhong et al., 2024). Likewise, higher environmental tax leads to reductions in CO_2 emissions and other waste products (Du et al., 2024; He et al., 2023; Jiang & Qiu, 2023; Kirikkaleli, 2023; Wolde-Rufael & Mulat-weldemeskel, 2023; Xu et al., 2023; Zhang & Zheng, 2023). However, some study revealed that environmental taxes have asymmetric effect on CO_2 emissions (Ibe et al., 2024).

In today's world, green technology is crucial to address the challenge of ongoing climate change worldwide (Chang et al., 2023; Chien et al., 2022). This is mainly done through investments in research and development towards the use of renewable energy sources (Khan et al., 2021; Kwilinski et al., 2024). For example, some studies show that technological innovations, especially green energy consumption, reduce carbon emissions by increasing economic growth (Sharif et al., 2023). Many studies suggest that the use of green energy reduces CO_2 emissions(Akram et al., 2023; Fang, 2023; Saqib&Dincă, 2024; Yang et al., 2024).

After reviewing the literature in Table 1, most studies used conventional frequentist mean regression such as moment quantiles regression method, ordinary least square (OLS), cross-sectional autoregressive distributed lag (CS-ARDL), pooled mean group (PMG), and generalized Method of Moments (GMM), Fourier -ADL cointegration, Spatial Durbin Model (SDM) among others. No reviewed study has used Bayesian panel regression to examine the relationship between natural resource extraction, environmental technology, and environmental taxation of carbon emissions. The aim of this study is therefore to fill this gap in the existing literature.

Table1: Summaryof empirical literatureonnatural resources, environmental technology & taxation and carbon emissions

Authors	Country	Time	Methodology	Main findings
a) Economic growth nexus carbon emissions				
1. Obobisa &Ahakwa (2024)	25 European countries	1990 - 2019	The fixed effect model and Generalized Method of Moments (GMM)	Economic growth or GDP per capita significantly increase CO_2emissions.
2. Hussain et al. (2023)	5 BRICS countries	1985 - 2019	OLS, fixed effect, Generalized Method of Moments	The effect of economic growth and natural resources extraction on carbon dioxide emission is positive.
3. Cao et al. (2022)	36 OECD countries.	1985 - 2018	Pooled Mean Group (PMG)	Economic growth increase CO_2emissions.
4. Raihan (2023)	Vietnam		Autoregressive Distributed Lag (ARDL)	Economic growth increase CO_2 emissions.
5. Raihan&Tuspekova (2022)	Brazil	1990 - 2019	Autoregressive Distributed Lag (ARDL)	Economic growth increase CO_2emissions
6. Hamdan (2024)	UAE	1981- 2020	Unit root test for time series stationarity	CO_2 emissions and economic indicators are negatively correlated. In a long-term there is no association between CO_2 emissions and economic indicators
7. Pradhan et al. (2024)	South Asian region, and the G-7 countries	1996 - 2021	Simultaneous regression models, and panel Autoregressive Distributed Lag (ARDL) models	GDP per capita positively contributes higher CO_2emissions.
8. Chen et al. (2023)	38 developing countries	1970 - 2021	Panel Data Estimations	The GDP per capita income increase CO_2 emissions.
9. Wang & Yang (2024)	China	1971-2019		CO_2 emissions are negatively related to natural resources
10. Khan & Hassan (2024)	141 developing economies	2000 - 2021	Method of Moment Quantiles Regression	High-Technology, GDP, and natural resource rents (NRR) increase CO_2 emissions
11. Alaganthiran&Anaba (2022)	20 Sub Saharan African (SSA)	2000 - 2020	Pooled Ordinary Least Square (OLS)	An increase in economic growth increases CO_2emissions
12. Chenetal (2025)	G-7 countries	1990-2022	Full Modified Least Square (FMOLS), quantile regression	Economic growth increase carbon emissions
13. Raihan et al. (2023)	Egypt	1990 -2019	Dynamic Ordinary Least Squares (DOLS)	The use of fossil fuel energy increase CO_2emissions

Authors	Country	Time	Methodology	Main findings
b) Natural resources rents and carbon emissions				
1. Rehman et al. (2024)	Pakistan	1971- 2019	Non-linear Autoregressive Distributed Lag	Oil rents haveasymmetric impact on CO_2 emissions, whereas coal rents reduces environmental sustainability
2. Shahbaz et al. (2024)	30 highly emitting countries	1995 - 2021	Generalized Method of Moments (GMM), Quntile regression	Coal rents show negative relationship with CO_2 emissions
3. Adedoyin et al. (2020)	BRICS	1990 - 2014	Dynamic Autoregressive Distributed Lag (ADRL)	Coal rents have negative impact on CO_2 emissions.
4. Zhou et al. (2024)	BRICS	1995 - 2019	Common Correlated Effects Mean Group, Augmented Mean Group, and Panel Quantile Regression	Natural resources (coal, gas, oil, forest, and mineral) rents deteriorate environmental sustainability in BRICS by increasing CO_2 emissions
5. Yu-Ke et al. (2022)	G-20 countries	1995 - 2018	Pooled Mean Group (PMG)	Rent on mineral resources, oil resources, and forest rent have a positive and significant impact on CO_2
6. Jia et al. (2024)	G-20 countries	2000 - 2021	Cross-Sectional Autoregressive Distributed Lag (CS-ARDL)	Rents from natural gas, oil, and forest resources increase CO_2 emissions
7. Chen et al. (2024)	6 transition countries	1970 - 2021	Quantile-on-Quantile Approach	Energy consumption positively affects both CO_2 emissions
8. Gershon et al. (2024)	17 selected African countries	2000 - 2017	Static panel estimation techniques	An increase in energy consumption negatively affects CO_2emissions.
9. Chen& Chen (2024)	China	1990 - 2022	Autoregressive Distributed Lag (ARDL)	Natural resources escalate CO_2 emissions in short-run and long-run
10. Voumik et al. (2023)	Five South Asian countries	1972 - 2021	Cross-Sectional Autoregressive Distributive Lag (CS-ARDL)	CO_2 emissions have been reduced due to natural resources rent.
11. Chen et al. (2023)	38 developing and industrialized countries	1970 - 2021	Panel Data Estimations	Natural resource rents increase CO_2 emissions.
12. Li et al. (2024)	152 countries	2002 - 2018	Moment Quantile Regression	Natural resource rent tends to promote the increase of CO2 emissions
13. Wang et al. (2024)	South Asian countries	1990 - 2021	Non-parametric Panel Estimation	Natural resources reduce CO2 emissions to attain carbon neutrality.
14. Shang et al. (2024)	World's top-ten carbon emitter countries	2004 - 2018	Method of Moment Quantile-Regression	Natural resource rent negatively affects ecological quality

Authors		Country	Time	Methodology	Main findings
c) Environmental tax and CO_2 emissions					
1.	Ibe et al. (2024)	South Africa	1995-2021	Non-linear Autoregressive Distributed Lag (NARDL)	Environmental taxes have an asymmetric impact on CO_2 emissions
2.	Du et al. (2024)	China	2015 - 2020	Difference in Difference	Environmental tax protection reduce carbon emissions
3.	Zhong et al. (2024)	282 cities in China	2018	DiD (difference in difference)	Environmental Protection tax reduce carbon intensity
4.	Kafeel et al. (2023)	selected OECD countries	2006 - 2020	Generalized method of moments (GMM) and instrumental variables 2 stage least square (2SLS) methods	Environmental taxes exhibit negative coefficients, indicating it reduces CO_2 emissions.
5.	Wolde-Rufael&Mulat-weldemeskel (2023)	20 European countries	1995 - 2012	Panel cointegration tests	Higher environmental tax reduce CO_2 emissions.
6.	Zhang& Zheng (2023)	G-7 countries	1990 - 2020	Cross-sectionally Augmented AutoRegressive Distributed Lags	Environmental taxes reduces CO_2 emission.
7.	He et al. (2023)	6 OECD countries		Auto-Regressive Distributed Lag (ARDL)	Environmental taxes plays a positive role in reducing CO_2emissions in OECD countries
8.	Jiang& Qiu (2023)	Brazil, China, India, and South Africa	1994 - 2019	Method of Moments Quantile Regression estimator	Environmental taxes only contribute to pollution in countries with higher emissions, whereas CO_2 emissions increase environmental taxes in all countries.
9.	Xu et al. (2023)	287 cities in China	2010 - 2019	Spatial correlation index	Environmental tax had a significant effect on reducing emissions of sewage, waste gases, and solid waste.
10.	Kirikkaleli (2023)	Netherlands		Fourier ADL cointegration, Fourier ARDL, and Fourier TY causality approaches	Environmentally related taxes cause the mitigation of environmental degradation.
d) Environmental technology and CO_2 emission					
1.	Kwilinski et al. (2024)	European Union	2007- 2020	Panel Correced Standard error(PCSE)	Environmental technologies and renewable energy reduce CO_2 emissions.
2.	Yang et al. (2024)	283 cities of China	2003 - 2019	Panel threeshold model	Digital Technology reduces carbon emissions

Authors	Country	Time	Methodology	Main findings
3. Sharif, Mehmood, et al. (2023)	USA	990 - 2019	quantile-on-quantile Augmented Autoregressive Distributed Lag	Green energy consumption mitigates CO_2emissions
4. Saqib&Dincă (2024)	BRICS	1995 - 2020	Panel NARDL	Environmental technology, and renewable energy reduce carbon emissions
5. Javed et al. (2023)	EU	1994 - 2019	Dynamic simulated ARDL (DYARDL)	Green technology innovation, renewable energy consumption significantly enhance the quality of the environment by lowering the ecological footprint
6. Sharif, Kartal, et al. (2023)	5 sovereign Nordic countries	1995 - 2020	Cross-sectional Augmented Autoregressive Distributed Lag (CS-ARDL)	Green technology and green energy reduce CO_2 emissions in the both short-run and long-run
7. Fang (2023)	32 provinces in China	2005 - 2019	Generalized Method of Moments (GMM)	Carbon emissions are negatively related to technology innovation
8. Akram et al. (2023)	G7 economies	1997 - 2019	Cross-sectional ARDL, common correlated effects mean group, augmented mean group, and panel quantile regression	Green energy drive towards carbon neutrality by reducing the stock of CO_2emissions
9. Sharif et al. (2023)	Six Association of Southeast Asian Nations (ASEAN-6)	1995 - 2018	CS-ARDL method	Impact of green energy and green investment on green technology innovation are positive on economic growth
10. Chang et al. (2023)	30 provinces of China	2003 - 2019	Panel Fixed-effect model, the Spatial Durbin Model (SDM), the System Generalised Method of Moments (SYS-GMM)	Environmental regulations positively moderate the impact of green knowledge innovation on CO_2 emissions reduction.
11. Shahbaz et al. (2024)	30 highly emitting countries	1995 - 2021	Generalized Method of Moments (GMM)	Environment-related technologies play a pivotal role in emission reduction.

3. Data sources and methodology

3. 1 Data sources

Table 2 shows the source of data and its measurements

Variable	Unit	Source
Economic growth (gdp)	GDP per capita at constant 2015 US$	WDI
CO_2 emissions	metric tons per capita	WDI
Coal_rent	Coal rents, percentage of GDP	WDI
Gas_rent	Natural gas rents, percentage of GDP	WDI
Forest_rent	Forest rent, (% of GDP)	WDI
Oil_rent	Oil rent, (% of GDP)	WDI
Mineral_rent	Mineral rent, % of GDP	WDI
Environmental technologies	% of all environmental technologies	OECD
Renewable	% of electricity	Our Word data
Environmental tax	Total % of environmental tax	OECD
Fossil fuels	Twh	Our Word data

NB: Data sources website are shown in the data availability statements, WDI=World Bank Development Indicators

3.2 Bayesian model estimations

The Bayesian panel data model can be expressed as follows:

$y_{it} = x'_{it}\beta + \propto_i + \gamma_i + e_{it}$.....Where $e_{it} \sim N\ (\mu_i, \tau)$ and $i = 1 \ldots, n$ and $\tau = \frac{1}{\sigma 2}$ (1)

y_{it}= environmental sustainability (CO_2) at country i and t = time,
x' show the vector of independent variables (environmental tax, environmental technology, natural resources, renewable energy, fossil fuel, economic growth),
$\propto_i$= Country specific effect
γ_i = Time specific effect
e_{it} = Error term
τ = precision or tau,
σ is sigma
β is a coefficient of unknown parameters
$\tau \sim gamma(a, b)$,
$\mu_i = X'_{it}\beta$.

Thus, country specific and time effect follow the normal distributions as follows:-

Likelihood (2)

CO_2 ~ normal (xb_CO_2,{sigma2}), where xb = Coefficient of all independent parameters including gdp, gdp^2, resource extraction (i.e. coal rents, forest rents, mineral rents, oil rents, natural gas rents), fossil fuels, renewable, environmental taxes and environmental technologies).

Priors (3)

{CO_2: gdp} ~ normal (0,10000)
{CO_2:gdp^2} ~ normal (0,10000)
{CO_2:coalrent} ~ normal (0,10000)
{CO_2: forestrent} ~ normal (0,10000)
{CO_2: mineralrent} ~ normal(0,10000)
{CO_2: oilrent} ~ normal(0,10000)
{CO_2: gasrent} ~ normal(0,10000)
{CO_2: fossil} ~ normal(0,10000)
{CO_2: renewable} ~ normal(0,10000)
{CO_2: environmentaltaxes} ~ normal(0,10000)
{CO_2: envinronmental tech} ~ normal(0,10000)
{CO_2:_cons} ~ normal (0,10000)
{U[cid]} ~ normal (0,{var_U})
{sigma2} ~ igamma(0.01,0.01)

Hyperprior:

{var_U} ~ igamma(0.01,0.01) (4)

Thus, to obtain Bayesian posterior distribution = prior's × likelihood (5)

We estimated the model using Metropolis-Hastings and Gibbs sampling while accounting the normal distribution with default prior (Byaro et al., 2023a). All parameters were given a normal prior with a mean of 0 and a precision of 0.001 (i.e. 10,000) and assigned a gamma (0.01, 0.01) as shown above. The estimation procedure was based on a Markov Chain Monte Carlo (MCMC) simulation to obtain a posterior distribution. We run a 10,000-iteration sample with a burn-in of 2500 and 10 thinning parameters to reduce autocorrelation.

4. Empirical results and interpretation

Table 3: Summary of descriptive statistics

Variable	Observations	Mean	Std. dev.	Min	Max
Economic growth (gdp)	312	9.658	1.191	6.47	11.032
Coal_rent	289	-3.422	3.547	-14.026	1.98
Forest_rent	309	-2.565	1.595	-5.62	0.098
Mineral_rent	292	-3.779	3.996	-16.699	1.501
Oil_rent	312	-1.601	2.461	-7.249	2.731
Natural gas_rent	294	-2.987	2.309	-10.752	2.007
Fossil	312	8.224	0.953	7.003	10.5
Renewable	312	2.756	1.107	-0.788	4.538
Environmental tax	263	0.415	0.55	-1.897	1.28
Environmental technologies	300	2.268	0.297	1.105	2.824

NB: All data are expressed in natural logarithm

Although it is important to test multicollinearity before regression model fit, is not a primary concern in panel data analysis where there are heterogeneous countries. However, we tested VIF and not reported here, and found that VIF of all natural resources extraction is less than 10, indicating no multicollinearity. Thus, we combined all independent variables in a single Bayesian estimation regression.

The results in Table 4 show that economic growth (GDP) increases CO_2 emissions in G-7 and BRICS countries. This is because the mean or median of GDP is positive on CO_2 emissions and its coefficients lie within the 95% credible interval. This implies that there are 0.95 probability that economic growth increases CO_2 emissions in these countries. We also checked whether Environmental Kuznets Curve (EKC) hypothesis is valid for G-7 and BRICS countries. If the sign of economic growth (i.e., GDP) and its square (i.e., GDP^2) are positive and negative, respectively, the Environmental Kuznet Curve hypothesis (EKC) is valid and statistically significant (Byaro et al., 2023a; Pata & Kartal, 2023). Our results reveal that EKC is valid in both BRICS and G-7 countries.

Table 4: Bayesian posterior regression estimates for CO_2 emissions in G-7 and BRICS countries

Parameters	Mean	Std. dev.	MCSE	Median	[95% credible interval]	
GDP	1.499	0.246	0.026	1.500	1.026	1.979
GDP^2	-0.075	0.013	0.001	-0.075	-0.100	-0.049
Coal rent	-0.001	0.002	0.000	-0.001	-0.007	0.004
Natural gas rents	0.015	0.004	0.000	0.015	0.007	0.023
Forest rent	0.030	0.010	0.000	0.030	0.010	0.051
Fossil fuel	0.642	0.061	0.012	0.650	0.494	0.751
Mineral rent	0.002	0.003	0.000	0.002	-0.003	0.007
Renewable energy	-0.082	0.009	0.001	-0.082	-0.102	-0.066
Oil rent	0.002	0.006	0.000	0.002	-0.010	0.014
Environmental technologies	-0.059	0.013	0.000	-0.058	-0.085	-0.033
Environmental tax	-0.023	0.013	0.001	-0.023	-0.049	0.004
_constant	-10.493	0.885	0.070	-10.489	-12.198	-8.741
var_U	0.953	0.558	0.033	0.819	0.343	2.354
sigma2	0.001	0.000	0.000	0.001	0.000	0.0014

Note: MCSE (Monte Carlo Standard Error)

The results also show that fossil fuels, forest rents and natural gas rents increase CO_2 emissions in G-7 and BRICS countries. This is because the mean or median of these parameter coefficient values lies within the credible interval of 95%. This implies that there is a 0.95 probability chance for fossil fuels, natural gas and forest rents to increase CO_2 emissions. The results reveal that renewable energy and environmental technologies reduce CO_2 emissions in these countries. This is because the mean or median of these parameters is negative and its coefficient value lies within the credible interval or probability value of 0.95.

Although the results show that environmental tax and coal rents reduce CO_2 emissions, its mean or median coefficient value lies within the negative and positive values of credible intervals indicating the uncertainty of these parameters to effectively mitigating CO_2 emissions. Likewise, mineral rents and oil rents show to increase in CO_2 emissions though the evidence still indicates uncertainty of these parameters to increase CO_2 emissions in G-7 and BRICS countries as the mean or median coefficients of these parameters lie between negative and positive credible intervals of 0.95 probabilities.

4.1 Robustness of the results

This robustness check aims to confirm the validity of Bayesian panel regression. Although Bayesian regression analysis shows that there is uncertainty in some natural resource rents (i.e. mineral, coal and oil) and environmental taxes in reducing or increasing CO_2 emissions in the BRICS and G-7 countries, we used the conventional frequentist quantile method of moments regression (MM-QR) to confirm whether environmental taxes and resource rents index increase or decrease CO_2 emissions. We constructed the natural resource rent index using Principal Component Analysis (PCA) from five variables, including coal rents, natural gas rents, forest rents, mineral rents, and oil rents. The reason for creating the PCA is to avoid the assumption that all rents are highly correlated and could lead to multicollinearity. The results are shown in Table 5.

The result shows that an environmental tax has a positive impact on the increase in CO_2 emissions in the BRICS and G7 countries. This confirms the uncertainty of the results indicated by the Bayesian regression in Table 4 as environmental tax can either reduce or increase CO_2 emissions. Both renewable energies and environmental technologies reduce CO_2 emissions in all quantiles as confirmed by Bayesian regression. The fossil fuels and natural resources index increases CO_2 emissions in all quantiles. This is also proven by the results of Bayesian analysis that natural gas rents and forestry rents increase CO_2 emissions in BRICS and G-7 countries. Although Bayesian analysis shows the uncertainty that coal rents, mineral and oil rents reduce or increase CO_2 emissions, quantile regression proves that the natural resource rent index increases CO_2 emissions. The overall results confirm that the results shown in Table 4 are valid.

Table 5: Method of moment quantile regression for CO_2 emissions

Variables			**Quantile**		**Mean**	**Variance**
	0.25	**0.50**	**0.75**	**0.90**	**Location effect**	**Scale effect**
GDP	1.278 ***	.802*	.182	-.320	.734**	-.600***
	(.267)	(.304)	(.396)	(.435)	(.299)	(.126)
GDP^2	-.032*	-.003	.034	.064**	.001	.036***
	(.015)	(.017)	(.022)	(.024)	(.017)	(.007)
Fossil fuel	.239***	.194***	.136***	.090**	.188***	-.055***
	(.015)	(.019)	(.031)	(.038)	(.019)	(.013)
Renewable energy	-.275***	-.263***	-.248***	-.235***	-.261***	.014*
	(.014)	(.016)	(.022)	(.027)	(.016)	(.008)
Environmental technologies	-.173***	-.204***	-.243***	-.276**	-.208***	-.088*
	(.052)	(.056)	(.077)	(.097)	(.057)	(.052)
Environmental taxes	.315***	.245***	.153	.079	.234***	-.038
	(.045)	(.075)	(.124)	(.169)	(.080)	(.033)
Natural resources index	.333***	.393***	.473***	.537***	.402***	.076***
	(.029)	(.041)	(.063)	(.073)	(.041)	(.022)
Constant	-8.469***	-6.01***	-2.814	-.224	-5.66***	3.09***
	(1.22)	(1.43)	(1.908)	(2.11)	(1.408)	.607
(N)	210	210	210	210	210	

Note: Robust standard errors are shown in parentheses ( ). The notation *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively, with *** representing $p < .01$, ** representing $p < .05$, and * representing $p < .10$

5. Discussion of results

Our study shows that economic growth (GDP) increases CO_2 emissions in G-7 and BRICS countries, and these findings concur with results from (Agyarko et al., 2023; Emre et al., 2022; Yousefi et al., 2023). Since the sign of economic growth (i.e., GDP) and its square (i.e., GDP^2) are positive and negative, respectively, the EKC is valid and statistically significant (Byaro et al., 2023a; Pata & Kartal, 2023). Our results reveal that EKC is valid in both BRICS and G-7 countries. The findings align with Environmental Kuznet Curve (EKC) which indicates as the economy grows the quality of the environment declines as more and more extraction of resources for economic gain affects the sustainability of the environment (Grossman & Krueger, 1991).

It should be noted that the BRICS and G7 countries have been experiencing economic growth for a long time due to industrialization. Therefore, the CO_2 emission rates observed today in these countries are the result of long-term accumulation. However, despite knowledge of the impacts and consequences, the question of economic growth and environmental sustainability remains a mystery for the world today. It is still common practice to sacrifice the environment for economic growth and even more difficult for international organizations to take action as some countries openly refused to comply with environmental sustainability. Take, for example, the 1997 Kyoto Protocol, which excluded China and India as developing countries despite being among the largest polluters, while the United States refused to ratify the protocol.

Countries like China have grown rapidly in these cycles through dependence on coal and oil, threatening international efforts to achieve breakthroughs in reducing carbon emissions. The studyby Wang & Yang (2024) expresses the role of economic growth through industrialization, which makes extensive use of fossil fuels, leading to CO_2 emissions and the depletion of natural resources. Although China is currently in transition, the damage caused is still significant (Cristea et al., 2022; Yousefi et al., 2023). For instance, CO_2 emissions from fossil fuels and industry in tons per person in China are continuously increasing from 2.9 tons in 1996 to 8 tons in 2022 (Our World in data, 2022). Likewise, CO_2 emissions from fossil fuels and industry in Brazil increased from 1 .7 tons per person in 1996 to 2.3 tons per person in 2021. This can also be seen in Russia, where CO_2 emissions are increasing from 10.7 tons per person in 1996 to 11.4 tons per person in 2022. In India, CO_2 emissions per person increased from 0.8 tons in 1996 to 2 tons in 2022. In contrast, the USA, France, Canada, Great Britain, Germany, South Africa and Japan were able to reduce CO_2 emissions from 1996 to 2022 (Our World in data, 2022).

The results also show that fossil fuels, forest rents and natural gas rents increase CO_2 emissions in the G-7 and BRICS countries. This proves a clear evidence for the RRC theory, which implies negative consequences of a strong dependence on the extraction of non-renewable resources, particularly relevant for fossil fuels, coal and minerals (Auty, 2002). Empirically, these results are consistent with the findings of (Manjang et al., 2023a), particularly in the case of fossil fuels for G-7 countries. The influence of fossil fuels on rising CO_2 emissions is also evident in other parts of the world, including Asian countries (Jun et al., 2021). It is obvious that fossil fuels are still the most widely used source of energy as they are still cheaper, accessible and easy to manage compared to other energy sources. The economic advantage of fossil fuels has led many investors to choose this type of energy instead of investing heavily in clean energy.

Rent payments specifically for natural gas rents, forest rents and fossil fuels do not reflect the degradation and pollution caused by the extraction of these resources in both G-7 and BRICS countries. Although our results show that coal rents minimize CO_2 emissions in the G7 and BRICS countries, the results are still uncertain as their mean or median coefficients lie between negative and positive credible intervals. This uncertainty could be related to the political regulation of CO_2 emissions, especially the change in political administration. Each political administration's approach to climate change may vary. Similarly, mineral and oil rents increase CO_2 emissions in G7 and BRICS countries, but the results are still uncertain. It is also important to note that the extraction and use of mineral and oil resources in the G-7 and BRICS countries might be certainly associated with CO_2 emissions. Normally, extracting and burning these resources in industry produce energy that releases CO_2 emissions. However, the uncertainty of mineral and oil rents to increase CO_2 emissions could be caused by changes in government policy on climate change, which can dramatically alter emissions trajectories. For example, global oil prices fluctuate due to supply-demand dynamics influenced by geopolitical events and technological advances in production methods. These fluctuations can lead to uncertainty about how much natural resources will be produced at any given time.

Our results also show that renewable energy and environmental technologies reduce CO_2 emissions in these countries. These results are similar to those of (Akwasi et al., 2022; Byaro et al., 2023b; Ghio et al., 2023; Manjang et al., 2023a; Sarfraz et al., 2022; Yousefi et al., 2023) indicating that renewable energy has proven to be an effective method for reducing carbon emissions. Technologies controls the CO_2 emissions by limiting the CO_2 production. Environmental technologies often focus on improving energy efficiency in industrial processes(Shahbaz et al., 2024). By optimizing energy consumption, industries can significantly reduce their CO_2 emissions. For example, advanced manufacturing techniques and equipment in G-7 and BRICS countries can reduce the energy required for production, resulting in less fossil fuel consumption. This means that environmental technologies provide energy sources that are clean, safe and can be used sustainably to benefit the environment and the economy. Further, technologies such as solar energy, hydropower, hydrogen energy, nuclear energy and natural gas are evidence of good energy sources with low to no CO_2 emissions. Previous studies that support environmental technologies to reduce carbon emissions includes (Kwilinski et al., 2024; Saqib & Dincă, 2024; Shahbaz et al., 2024; Sharif, Kartal, et al., 2023).

It is also worth noting that environmental technologies have high acquisition, operation and maintenance costs compared to fossil fuels (Yousefi et al., 2023). On the other hand, their accessibility is also limited, for example in the case of nuclear energy. The study by (Yousefi et al., 2023) explains that one of the reasons the UK is falling from first to ninth place in clean energy use is political obstacles that include competing interests, short-term priorities and unsustainable energy policies. Other countries where clean energy use has declined include Italy and France due to the high cost of clean technologies, particularly investments in nuclear energy (Yousefi et al., 2023).

In this study, our results also show the uncertainty of environmental taxes to reduce CO_2 emissions as their mean or median coefficient value lies within the negative and positive values of the credible interval. The effectiveness of environmental taxes in reducing CO_2 emissions is also questionable. For example, one of the main causes of uncertainty regarding environmental taxes is their economic impact. Environmental taxes can increase operating costs for companies, especially in energy-intensive industries. Companies may face higher production costs, which in turn increase the prices of goods and services. Meanwhile, reaching a consensus on the design and implementation of carbon taxes between G-7 member states and BRICS countries is challenging due to different national interests and priorities. Each country has its own economic structure, energy resources and political climate, which influence its standpoint on environmental taxation. On the other hand, factors such as institutional capacity could also influence this uncertainty (Azam et al., 2021). Institutions play an important role in improving the effectiveness of environmental taxation and the use of renewable energy (Abbas et al., 2022; Yasmeen et al., 2023). This means that appropriate institutions have effective enforcement measures, procedures and due diligence in place to support environmental taxes to reduce CO_2 emissions. However, many studies support the fact that environmental taxes reduce CO_2 emissions, including (Du et al., 2024; Ibe et al., 2024;Zhong et al., 2024;Kafeel et al., 2023;Wolde-Rufael &Mulat-weldemeskel, 2023;He et al., 2023). Overall, our robustness test confirms that environmental taxes and the extraction of natural resources index raise CO_2 emissions in BRICS and G-7 countries, even though Bayesian regression results are uncertain regarding the impact of these variables on CO_2 emissions.

6. Conclusion and policy implications

This study examines the relationship between natural resources extraction, environmental technology, environmental taxation and carbon emissions in the context of the Environmental Kuznets Curve (EKC) hypothesis, incorporating renewable energy use, fossil fuels and economic growth as controlling factors. Using Bayesian panel regression, we analyze data from 1996 to 2021 for twelve countries within the G-7 and BRICS cohorts. Our results show a consistent pattern in which the extraction of various natural resources – forest rents and natural gas rents – as well as fossil fuels and economic growth contribute to increases in CO_2 emissions in these countries. Although our results show that coal rents minimize CO_2 emissions in the G7 and BRICS countries, the results are still uncertain according to Bayesian regression. This uncertainty could be related to the political regulation of CO_2 emissions, especially the change in political administration. Mineral and oil rents increase CO_2 emissions in G7 and BRICS countries, but the results are also uncertain. The uncertainty of mineral and oil rents could be caused by changes in government policy on climate change, which can dramatically alter emissions trajectories. In contrast, we found evidence of renewable energy and environmental technologies to reduce CO_2 emissions in these countries.

Our results also show the uncertainty of environmental taxes to reduce CO_2 emissions. One of the main causes of uncertainty regarding environmental taxes is consensus on the design and implementation of carbon taxes between G-7 member states and BRICS countries. Each country has its own economic structure, energy resources and political climate, which influence its standpoint on environmental taxation. However, our robustness test confirms that environmental taxes and natural resources index increase CO_2 emissions in these countries.

We recommend practical policy implications that engage these countries to pursue economic growth without compromising environmental quality. Thus, G-7 and BRICS countries should continue to use environmental technologies to expand industrialization to curb more CO_2 emissions towards carbon neutrality by 2050. In addition, these countries should make transition from the use of fossil fuels to more renewable energy options to reduce CO_2 emissions. To ensure the effectiveness of environmental taxation in reducing CO_2emissions in G-7 and BRICS countries, conventions such as the Kyoto Protocol should be refined and enforced to ensure that all environmental conditions and target for achieving zero carbon are agreed. There should also be consistent measures on environmental taxes and design to be agreed and implemented. Enforcing environmental taxes has the chance to transform countries into low-carbon economies, but the outcome may require further policy changes and agreement between G-7 and BRICS countries.

G-7 and BRICS countries should strengthen and continue to enforce environmental technologies and policies to track and analyze the impacts of industrialization and green energy use on CO_2 emissions. To effectively reduce CO_2 emissions through natural resource management, we recommend policies that focus on sustainable practices and technological innovations to strike a balance between natural resources (coal, minerals, oil, natural gas and forest) while reducing their CO_2 emissions. The study offers actionable insights for policymakers in other developing countries aiming to balance economic growth, natural resources extraction and environmental taxation with CO_2 emissions.

The main limitation of this study is the use of Bayesian regression as it utilizes prior knowledge. Any change in prior information is also likely to change the results. Despite this limitation, the results are valid because prior knowledge is required for each parameter to determine the posterior probability. Likewise, robustness test confirm the validity of the findings. Future studies should focus on the effects of environmental taxes, technology and natural resources in developing countries using other advanced econometric methods.

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Availability of data and materials

The data was extracted from public available database:

(i) World Bank Development Indicators (2023). https://databank.worldbank.org/source/world

(ii) OECD data (2022) https://www.oecd.org/en/data.html and Our World in Data (2022) https://ourworldindata.org/co2-and-greenhouse-gas-emissions#explore-data-on-co2-and-greenhouse-gas-emissions

Declarations

We declare no competing interest

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