

Government Spendings and Environmental Stewardship: Assessing the Economic and Environmental Impacts of Energy Consumption

Muhammad Adil*, Hafiz Muhammad Rafay, Ramla Alkubra, Iqra Shabbir

UE Business School, Division of Management and Administrative Sciences, University of Education Lahore, Punjab, Pakistan.

*Email: msf23005553@ue.edu.pk

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ABSTRACT

The demand for energy and its effects on the environment has been debated for several years due to continued economic developments. According to IEA (2023), global energy-related CO₂ emissions significantly peaked at an unforeseen level in 2023, especially in developing countries. Furthermore, this statistic highlights the need to increase environmental protection expenditures to address pressing environmental concerns. Therefore, this study investigates the moderating role of environmental protection expenditures on the associations of total energy consumption with both economic growth and CO₂ emissions. For this purpose, a panel data set of 30 Chinese provinces for the years 2012-2023 was included. According to estimation results through panel-corrected standard errors and generalized method of moments, energy consumption significantly and positively promotes economic growth and also contributes to increased CO₂ emissions. In the moderation case, the study found that environmental protection expenditures significantly diminish the CO₂ emissions caused by energy consumption while boosting economic growth. In light of these findings, the government should raise expenditures in environmental protection programs to form favourable conditions for economic growth and mitigate the impacts of CO₂ emissions.

Keywords: Economic Growth, Energy Consumption, CO₂ Emissions, Environmental Protection Expenditures

JEL Classifications: Q43, Q53, Q56, H23, O47

1. INTRODUCTION

Human development has enormously depended on energy consumption for centuries. Indeed, the global need for energy has increased at a rapid rate over recent decades due to fast industrialization, escalating urbanization as well as economic growth, particularly in developing countries (Ali et al., 2022; Scheffran et al., 2020). Most countries are striving to sustain the economic growth achieved through the utilization of energy sources in manufacturing and development. Akin to human and capital, neoclassical growth theories regard energy as a productive input into the growth process that supports industrial processes, movement, creation and distribution of goods and services (Rumanzi et al., 2021). Energy consumption

is increasing significantly in developing countries because of continuous industrialization and infrastructure expansion (Salahuddin and Gow, 2019; Bhattacharya et al., 2016). In the developed countries there might be a steady drop or at least stabilization of energy consumption due to transition in to services-oriented industries and energy efficient technologies (Ozcan et al., 2020). With the increasing global demands for energy, burning of the fossil fuels has resulted to higher emission of CO₂ among other greenhouse gases (Wang et al., 2021). The intergovernmental panel on climate change (IPCC) has stated the ever-increasing levels of CO₂ emanations are critical in driving global warming, and thus putting ecosystems and economic stability at risk globally (Mehmood et al., 2022). Consequently, countries are confronted with the difficult dilemma of trading off

between attaining long-term economic growth and minimizing natural deterioration.

This research examines the consequence of total energy consumption on economic growth and CO₂ emissions by assessing China's provincial data. China is the second-largest economy in the world and it grew a lot economically over a few decades. The growth is directly linked to the country's energy consumption (Gahlot and Garg, 2024). The country's energy consumption pattern is highly suited to rapid industrialization, urbanization, and infrastructure development that makes it one of the biggest energy consumers worldwide (Du et al., 2024; Hussain and Zhou, 2022). The total energy usage in China was about 161.9 exajoules in 2023, representing a 5.5% increase from 2022 (CEIC, 2025). There is no economy in the world today which is not powered by energy. China depends mainly on coal and other fossil fuels, and this reliance results in environmental costs. In 2023, the energy consumption resulted in the highest CO₂ emissions ever worldwide (IEA, 2023). China stands as the largest emitter of CO₂ in the world because of high energy consumption rate. With about 31% of world emissions, China was the largest emitter of CO₂ in 2023 (Carbon Brief, 2023). This alarming report underlined the paramouncy of addressing the climate challenges as well as achieving sustainable economic development. Today's challenge is how to use energy as a means of economic growth without endangering the environment. Therefore, China has heavily invested in environmental protection initiatives in the light of these environmental issues. The Chinese government has made clear pledges to cut down on carbon emissions. In accordance with the Paris Agreement, their plan is to reduce the carbon intensity, and achieve carbon-free up to the year 2060 (Ministry of Ecology and Environment, 2021). Additionally, by that same year, China is expected to invest 17 trillion dollars in developing green infrastructure to reach its carbon neutrality goal (Shalal, 2022).

Numerous empirical researches have been carried out to establish the link between energy consumption, CO₂ emissions and economic growth. But we have introduced a novel concept by incorporating environmental protection expenditures as moderating variable. Therefore, our study focuses on the energy-growth-environment nexus and government actions, particularly spendings on environmental protection. For our investigation, we have focused on province level panel data of China. For the data analysis, we applied panel-corrected standard errors regression. Additionally, we employed a two-step system of GMM regression to address the issue of endogeneity and conduct robustness checks. Hence, our investigation will guide policymakers in China and other developing countries towards economic expansion while maintaining the integrity of the environment.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1. Total Energy Consumption and Economic Growth

Tang et al. (2016) employed the Solow growth model with the aim of revealing the importance of energy usage in the Vietnamese economic growth. The study's outcomes through cointegration

and Granger causality techniques uncovered that the use of energy contributes positively to the Vietnamese economic expansion. Zhixin and Xin (2011) carried out the study by employing the Cobb-Douglas production function and applying provincial data of Shandong for the years 1980-2008. Their analysis through GMM has shown that an upsurge in energy usage boosts the economic expansion. Moreover, Salahuddin and Gow (2019) explored a time series dataset of Qatar from 1980 and 2016 using ARDL approach and discovered that energy usage contributes to financial prosperity. In their study examining thirty-eight of the most energy-consuming nations, Bhattacharya et al. (2016) also emphasized that energy is a way of raising economic development. Their study results revealed that regenerative energy significantly boosts the economic production up to 57% in chosen countries. Moreover, Gahlot and Garg (2024) utilized the science mapping approaches in order to perform an extensive bibliometric study of 409 academic articles. The evidence recovered from the prior research studies revealed that energy usage significantly influences economic progress. Considering the discussion, we hypothesize that:

- H₁: The consumption of energy has a positive influence on economic growth.

2.2. Energy Consumption and CO₂ Emission

According to Acheampong (2018), the energy usage causes environmental degradation with the upsurge of CO₂ emissions. The research used the System-GMM regression technique to analyse the data of 116 countries for the years 1990-2014. However, Wang et al. (2016) revealed a unidirectional causal association among energy usage and CO₂ emanations amid multifaceted development situation confronted by modern China. Their study revealed that environmental deterioration occurs in China as a result of high energy usage. Further, Ardakani and Seyedaliakbar (2019) studied the data of seven oil-abundant MENA countries to gauge the impact of energy usage on CO₂ emanation. Their research pointed out a direct relation between energy usage and CO₂ outflow. Khan et al. (2019) investigated the Pakistani data for the years 1971-2016 in order to gauge the influence of energy usage on CO₂ emanations. The analysis through dynamic ARDL simulation evidenced that the dependency on energy plays a significant role in the upsurge of CO₂ emanations. Also, the study of Ali et al. (2022) on Chinese data sheds light on the link among energy usage and carbon emanations intensity. The results obtained through the ARDL simulation method highlighted that energy usage intensifies the carbon emanation in China. Considering the overhead debate, we hypothesize that:

- H₂: Energy consumption is positively associated with CO₂ emissions.

2.3. Moderating Role of Environmental Protection Expenditures

The study of Feng et al. (2022) shed light on the linkage among government expenditure and green economic outcomes by leveraging the data of BRI nations. The study emphasized that the government is required to spend significantly, mainly in sustainable energy sources, to avoid an escalation in CO₂ emissions through energy usage. Wawrzyniak and Doryń (2020) confirmed the direct correlation among energy consumption and

CO₂ emissions in selected thirty three emerging markets for the years 1995-2014. Their study also indicates that government investments in energy efficiency and cleaner technologies alters the economic development-emanations association. Donkor et al. (2022) confess that government expenditure on the environment can act as a mitigator to the energy consumption-environment quality relationship. This moderation becomes particularly important in those countries where the economic growth often consequences in the augmented level of CO₂ emanations. Further, Tan and Uprasen (2022) investigated government initiatives role through FDI on the energy consumption by utilising the BRICS nations' 1990-2015 statistics. Their conclusions through GMM regressions suggested that more government expenditure on energy transitions can dampen the ecological effect of economic development. In addition, they revealed evidences that relative state funding for investing in research and development of novel hi-tech and efficient energy facilities helps decrease CO₂ emissions while maintaining economic progress. Wang et al. (2022) explored the N-11 countries and argued that that financial development and government support for renewable energy help decouple economic development from ecological deterioration. Considering the following debate, we hypothesize that:

- H₃: Environmental protection expenditures positively moderate the link between energy consumption and economic growth.
- H₄: Environmental protection expenditures negatively moderate the link between energy consumption and CO₂ emissions.

3. RESEARCH METHODOLOGY

3.1. Database and Variables

For empirical analysis, we utilized a panel dataset of 30 Chinese provinces for the years 2012-2023. The dataset has a large number of cross-sections (N) as compared to the time period (T), with a total of 360 observations. In this study, the independent variable is total energy consumption (TEC). We gauged the TEC as the sum of both renewable and non-renewable energy usage in Chinese provinces during the study period. Besides, we involved two dependent variables: Economic growth (EG) and CO₂ emissions (COE). In addition, we incorporated environmental protection expenditures (EPE) as a moderating variable. The

data was obtained from the Statistical Yearbook and Energy Statistical Yearbook databases of China. The statistics regarding environmental protection expenditures was sourced from the Statista database (Statista, 2023). Table 1 provides the summary of study variables along with their acronyms and measurements.

3.2. Econometric Models and Methodology

To scrutinize the effect of TCL on EG and COE, we used the following baseline regression models.

$$EG_{i,t} = \alpha + \beta_1 (TEC_{i,t}) + \beta_2 (EPE_{i,t}) + \beta_3 (COVID19_{i,t}) + \varepsilon_t \quad (1)$$

$$COE_{i,t} = \alpha + \beta_1 (TEC_{i,t}) + \beta_2 (EPE_{i,t}) + \beta_3 (COVID19_{i,t}) + \varepsilon_t \quad (2)$$

$$EG_{i,t} = \alpha + \beta_1 (TEC_{i,t}) + \beta_2 (EPE_{i,t}) + \beta_3 (COVID19_{i,t}) + \beta_4 (TEC \times EPE_{i,t}) + \varepsilon_t \quad (3)$$

$$COE_{i,t} = \alpha + \beta_1 (TEC_{i,t}) + \beta_2 (EPE_{i,t}) + \beta_3 (COVID19_{i,t}) + \beta_4 (TEC \times EPE_{i,t}) + \varepsilon_t \quad (4)$$

Here, constant term is denoted by α , the slope coefficients are represented by β , the subscript t (where t = 1, 2., T) denotes the time frame and the subscript i (where i = 1, 2., n) indicates the count of cross-sections (provinces). An error term (ε_t) is also utilized to address any unobserved factors that might affect the dependent variables. Equations 1 and 2 illustrate the direct relationship between energy consumption and economic growth, as well as CO₂ emissions. Equations 3 and 4 present the moderating role of environmental protection expenditures with interaction terms. Figure 1 presents the conceptual model of the current study.

We applied various statistical techniques in order to gain a clear understanding of the data's characteristics. Without a thorough diagnosis of the data, choosing appropriate regression techniques is essentially guesswork, as the main regression estimates must match the identified data characteristics. So, we applied specific diagnostic tests to describe the characteristics of the data. These include Wald test for heteroskedasticity test, Wooldridge test for autocorrelation and Pesaran cross-sectional dependence test. These tests provide us with the ground to utilise PCSE regression, which we applied as our primary regression technique. PCSE estimator is better suited to our case, where each of the 30 provinces has data spanning 12 years. Further, Beck and Katz (1995) proposed the

Table 1: Variables description

Variables	Acronyms	Measurement	Explanation
Dependent variables			
CO ₂ Emission	COE	Kilotons (kt)	The total quantity of carbon dioxide emitted into the atmosphere, measured in kilotons.
Economic growth	EG	GDP (billion yuan)	The total economic output measured in billions of Chinese Yuan
Independent variable			
Total energy consumption	TEC	Kilowatt-hours per person	The total energy usage, combining renewable and non-renewable sources, is measured in kilowatt-hours per person.
Moderator variable			
Environmental protection expenditures	EPE	Billion yuan	The financial resources allocated by the government to prevent, control, and reduce environmental damage and resource depletion
Control variable			
COVID-19 pandemic	COVID19	Binary variable	The presence (indicated by a value of 1) or absence (indicated by a value of 0) of impacts associated with the COVID-19 epidemic

Source: Authors' derivation from study data

PCSE estimator to manage the case when T is $>N$. They argued that PCSE regression is more efficient and produces much accurate standard errors than GLS or OLS. Furthermore, we employed a two-step system GMM regression to tackle the endogeneity problem and increase the trustworthiness of the primary findings.

4. RESULTS INTERPRETATION

Table 2 provides the summary statistics of the variables. The sample includes the variables from the data of 30 Chinese provinces between 2012 and 2023. The average value of economic growth indicating that Chinese economy has continued to grow steadily. Besides, a higher standard deviation value indicating noteworthy variability among provinces regarding economic growth. Moreover, the high average value of CO₂ emission indicates that the provinces have shared substantial levels of carbon output during the study period. Further, energy consumption has a significant average value. The substantial average value implies that energy usage in high Chinese regions. The key descriptive statistics indicative of China's ongoing transitions in energy consumption are noteworthy.

Table 3 presents the results of the pairwise correlation analysis and the variance inflation factor (VIF). The correlations between study variables with large coefficient values might indicate the possibility of multicollinearity (Shrestha, 2020). Any variable causing statistical confusion should be eliminated from the econometric framework because strong correlation among selected variables can result in inaccurate regression coefficients. However, in our case, the correlation values are observed within substantially permissible bounds, excluding the likelihood of significant multicollinearity between the variables. Further, we have also utilized VIF to further substantiate our concerns about multicollinearity aside from examining pairwise correlation. Studenmund (2000) indicated that a variable with VIF value >10

can cause multicollinearity issue. As a result, that variable ought to be excluded from the econometric model during the phase of statistical analysis. Our findings using this method are quite encouraging as the calculated values of each variable are almost 1, indicating the absence of multicollinearity.

Table 4 reports the outcomes of three-unit root tests, including Levin-Lin-Chu and Fisher-type (ADF) tests. We conducted unit root tests to assess if the data is stationary or non-stationary by following Choi (2001) to ensure the accuracy of econometric models. Conducting unit root tests in panel data is crucial for obtaining a consensus-based perspective and minimizing bias stemming from the sample data. The notable P-values from our results suggest that the variables are stationary at the base level under common acceptance standards. Further, we conducted cross-sectional dependence analysis by using Pesaran CD test. In panel data scrutiny, Pesaran CD tests is essential and ignoring cross-sectional dependence can provide skewed and uneven outcomes in econometric estimations. In our case, the P-values of all variables are $<1\%$, indicating the presence of cross-sectional dependency in the dataset.

Table 5 reports the findings of modified Wald and Wooldridge tests. We have applied both tests on each model of the study separately since the quantity of cross-sectional units N exceeds the duration of time periods T in our panel data. The test statistics for each model show significance at a level lower than 1% , which concludes that the hypothesis of heteroskedasticity in this sample of provinces is valid. Based on the results, we can dismiss the null hypothesis of homoscedasticity, as our data shows evidence of heteroskedasticity. In addition, we have used the Wooldridge test for inquiry into possible autocorrelation among the residuals of the panel data regression models as outlined by Drukker (2003). The test-stats are proved to be significant because P-value of each model is $<1\%$. The results allowed us to conclude that autocorrelation is exist in our panel data.

Figure 1: Conceptual framework of the current study

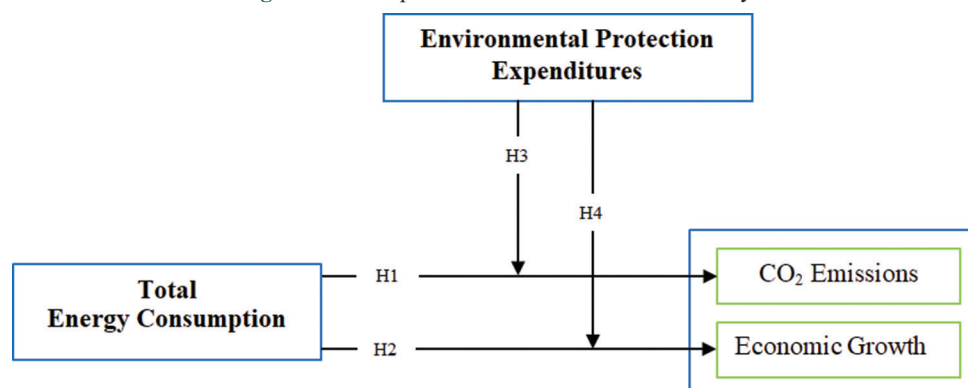


Table 2: Descriptive statistics

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
EG	360	23524.7	19714.2	1081.27	110760.94
COE	360	975845	886214	771907	109446
TEC	360	27424.41	3026.483	23821.6	33089.07
EPE	360	0.64773	0.08376	0.54553	0.79044
COVID19	360	0.083	0.277	0	1

Descriptive statistics computed by authors using study data

4.1. Main Empirical Findings

Table 6 reports the results from the primary regression analysis conducted using the PCSE estimation method. We utilized the PCSE estimator as our primary regression method due to its greater suitability for cross-section-dependent data, which applies to our study involving 30 provinces with 12 years of data for each. Also, PCSE estimator efficiently addresses autocorrelation and heteroskedasticity issues in the panel data (Adil et al., 2025; Reed and Webb, 2010). Beck and Katz (1995) highlighted the superiority of PCSE estimator and stated that the FGLS estimator yields underestimated standard errors, which can be adjusted by PCSE estimator. In Model 1, the coefficient value of β_{TEC} (1.6502***) is revealing significant positive link between TEC and EG. The findings show that the energy consumption results in economic development. An increased energy consumption accelerates technical innovation coupled with industrial development that foster the economic growth (Tang et al., 2016; Zhixin and Xin, 2011). In their study, Eggoh et al. (2011) contended that growth is boosted by increasing energy consumption and energy matters the most for emerging nations regarding industrialization and economic evolution. Hence, the results support our hypothesis H_1 .

Moreover, in Model 2, the statistically significant coefficient value of β_{TEC} (1.2732***) indicates a positive association among TEC and COE. The results suggesting that greater energy consumption, especially fossil energy sources lead to CO₂ emanations due to combusive processes through which carbon dioxide is released into the environment. By suggesting that energy usage causes ecological deterioration with rise in COE, Acheampong (2018) confirmed a positive association among energy consumption and CO₂ emanations. This relationship is normally seen in developing countries where there is high energy intensity for production and development of infrastructure hence comes with high emission rates (Ezekwugo et al., 2022; Wang et al., 2016). Consequently, this finding supports our hypothesis H_2 .

Furthermore, the findings of the moderator variable β_{EPE} in also reported in Table 7. We aim to assess how investments in environmental protection by government impact the connection

among energy usage, carbon emanations, and economic progress. Our findings reveal that β_{EPE} significantly and positively moderates the association among TEC and EG. This is indicated by the significant positive coefficient value of $\beta_{TEC \times EPE}$ (2.3908***) in Model 3. Our analysis indicates that energy consumption positively influences economic progress. Moreover, this effect is significantly improved when government allocate additional funding for environmental programs. According to Moshiri and Daneshmand (2020), the biggest advantage of environmental protection expenditures is that this spending helps to reduce the ecological cost of using energy resources while supporting economic development. In the same vein, Onofrei et al. (2020) observed that environmental investments can orient economies towards green sources of energy thereby dissociating economic development from high energy intensity particularly in the emergent economy (Hussain et al., 2025; Khan et al., 2019). Based on this finding, we can accept our hypothesis H_3 . Moreover, the findings reveal that β_{EPE} significantly and negatively moderates the link among TEC and COE. This is indicated by the significant negative coefficient value of $\beta_{TEC \times EPE}$ (-1.9542***) in Model 4. The finding suggests that governments can reduce the adverse influence of energy usage on carbon releases by allocating resources for environmental projects. For example, Wang et al. (2021) found that government-funded environmental projects help in reducing the COE by encouraging the adoption of green technologies in energy use. Likewise, Lin et al. (2023) pointed out that the investments made in the environment protection minimize COE levels as industries embrace changes that enhance their sustainable performance. On the basis of this finding, we can accept our hypothesis H_3 .

4.2. Endogeneity and Robustness Check

Endogeneity is a common challenge in panel-data analysis (Ullah et al., 2018). To address it, we estimated a dynamic model using system GMM. As stated in the methodology section, we used the two-step system GMM to tackle endogeneity issue and to verify the reliability of our main results. This approach is preferable to other dynamic regression methods when the dataset is contemporaneous ($N > T$). We chose system GMM over differenced GMM because it produces more superior results and allowing for better control over endogeneity matters (Roodman, 2009). Tables 8 and 9 report the results obtained from the two-step system GMM approach. Models 1 and 2 highlight the effects of energy usage and CO₂ emits on economic growth, respectively. Whereas Models 3 and 4 report the results of the moderating influence of β_{EPE} on the relationship between β_{TEC} , β_{EC} and β_{COE} . The two-step system GMM findings reveal that the coefficients' signs match those of

Table 3: Results of pairwise correlation and VIF analysis

Variables	EG	COE	TEC	EPE	COVID19	VIF
EG	1.000					-
COE	0.319*	1.000				-
TEC	0.584*	0.137*	1.000			1.02
EPE	0.182*	0.425*	0.061	1.000		1.42
COVID19	0.221*	0.553*	0.085	-0.045	1.000	1.67

Source: Authors' calculations from study data

Table 4: Findings of unit-root and cross-sectional dependence tests

Variable	Levin-Lin-Chu		Fisher-type (ADF)		Pesaran CD	
	t-stat	P-value	t-stat	P-value	t-stat	P-value
EG	-1.1647	0.0346	78.9211	0.0513	64.272	0.000
COE	-3.9944	0.0000	235.2920	0.0000	72.25	0.000
TEC	-6.5215	0.0000	200.1914	0.0001	12.28	0.000
EPE	-2.7002	0.0035	83.1192	0.0258	72.25	0.000
COVID19	-4.5732	0.0000	98.7201	0.0496	72.25	0.000

Authors' calculations based on study data

Table 5: Findings of heteroskedasticity and autocorrelation tests

Modified Wald test for groupwise heteroskedasticity				
Test Statistic	Model 1	Model 2	Model 3	Model 4
Chi-square	3232.63	59.32	5022.26	62.85
Sig	0.0000	0.0061	0.0000	0.0004
Accept/reject	Accept	Accept	Accept	Accept
Wooldridge test for autocorrelation in panel data				
F-stat	113.653	318.490	107.952	309.793
Sig	0.0000	0.0000	0.0000	0.0000
Accept/reject	Accept	Accept	Accept	Accept

Authors' calculations based on study data

Table 6: Findings of PCSE regression

Variables	Model 1		Model 2	
	Coefficient	P-value	Coefficient	P-value
TEC	1.6502***	0.000	1.2732***	0.002
EPE	-2.4850	0.138	1.4107***	0.000
COVID19	7840.6***	0.000	1538.9***	0.000
n	360		360	
R-squared	0.4493		0.5893	
Wald Chi-square	1633.69***	0.000	33238***	0.000

Source: Authors' calculations based on study data. The asterisk symbols (*, **, ***) signify the 10%, 5%, and 1% significance levels

Table 7: Findings of PCSE regression

Variables	Model 3		Model 4	
	Coefficient	P-value	Coefficient	P-value
TEC	0.1398	0.716	1.0730***	0.000
EPE	-2.3173***	0.008	1.4507***	0.000
COVID19	8721.0***	0.000	13578***	0.000
TEC×EPE	2.3908***	0.000	-1.9542***	0.000
n	360		360	
R-squared	0.4618		0.5945	
Wald Chi-square	1756.7***	0.0000	65046***	0.0000

Source: Authors' calculations based on study data. The asterisk symbols (*, **, ***) signify the 10%, 5%, and 1% significance levels

Table 8: Two-step system GMM results

Variables	Model 1		Model 2	
	Coefficient	P-value	Coefficient	P-value
TEC	1.7003***	0.000	1.2105	0.000
EPE	1.6003***	0.000	1.7277***	0.000
COVID19	9028.8***	0.000	1349.4***	0.000
AR (1)		0.000		0.000
AR (2)		0.901		0.851
Sargan test	157.58	0.000	294.80	0.000

Source: Authors' calculations based on study data. The asterisk symbols (*, **, ***) signify the 10%, 5%, and 1% significance levels

Table 9: Two-step system GMM results

Variables	Model 3		Model 4	
	Coefficient	P-value	Coefficient	P-value
TEC	1.5606***	0.000	1.7781**	0.027
EPE	1.7898	0.244	1.6846***	0.000
COVID19	8681.9***	0.000	1344.3***	0.000
TEC×EPE	1.7684***	0.000	-1.8026*	0.051
AR (1)		0.000		0.000
AR (2)		0.817		0.749
Sargan test	157.78	0.000	294.82	0.000

Source: Authors' calculations based on study data. The asterisk symbols (*, **, ***) signify the 10%, 5%, and 1% significance levels

our prior estimators, PCSE. Consequently, our analysis outcomes are reliable and stable throughout distinct estimators.

5. CONCLUSION

This study highlights the moderating role of environmental protection expenditures on the relationships between energy consumption and economic growth, as well as CO₂ emissions. For this purpose, a panel data set of 30 Chinese provinces for the years 2012-2023 was used. Using PCSE and GMM regressions, we found that energy consumption contributes positively to economic growth, but higher energy use also drives up CO₂ emissions. In the moderation case, the results shed light on the beneficial role of environmental protection expenditures in the economic growth due to energy consumption. Moreover, these expenditures also proved to be effective in tackling CO₂ emissions.

Regarding policy implications, policymakers should integrate environmental considerations into economic planning. In today's high-energy consumer economies, allocating environmental protection expenditures is now paramount for ecological protection. Government bodies should incorporate environmental protection spending into their national development plans. In China, energy usage is closely tied to economic progress due to the country's energy-intensive industrial environment. These funds should specifically be allocated to regions that yield economic productivity and have high emissions. Policymakers should legislate a year-on-year increase in environmental protection expenditures as a fixed percentage of the country's GDP. Also, they should ensure that funding keeps pace with economic expansion. Furthermore, these green initiatives are crucial for China to achieve its goal of achieving carbon neutrality by 2060. Hence, environmental protection expenditures should be the first-line instrument in China's green development strategies.

This study has some limitations that create space for future studies. Our panel dataset consists of a specific time period. Additionally, we have focused only on provincial-level panel data of a single country. This can limit the generalizability of the study results into other regions. Hence, future studies can perform inter-regional analysis. Furthermore, future studies can execute analysis by disaggregating total energy consumption into renewable and non-renewable sources. Besides, future studies can also incorporate green technological advancements and clean energy incentives as moderating factors.

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