frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 04 January 2023
DOI 10.3389/fenvs.2022.1066221

RETRACTED

An empirical analysis of FDI and institutional quality on environmental quality and economic growth, evidence from the panel of asian oil-producing and non-oil-producing economies

Yi Yang[1], Xiaobing Xu[2], Jiemin Yin[3] and Taiming Zhang[4]*

[1]School of Economics, Lanzhou University, Lanzhou, China, [2]Lanzhou Branch of China Minsheng Bank, Lanzhou, China, [3]School of law, Shanghai University of Finance and Economics, Shanghai, China, [4]Business School, Finance Department, University of Edinburgh, Edinburgh, United Kingdom

This study applies the augmented mean group (AMG) estimation technique to investigate whether institutional quality and FDI contribute to economic growth and environmental quality in emerging Asian oil-producing and non-oil-producing countries during the period 1975–2020. The estimation of AMG strategy indicates that for every 1% increase in FDI, institutional quality and carbon emissions can significantly boost economic growth by 0.882%, 0.659%, and 0.605%, respectively. Likewise, trade liberalization, transport infrastructure and urbanization can significantly boost economic growth. Long-term variable elasticity coefficients based on carbon emissions model suggest that FDI can stimulate carbon emissions, thereby validating the Pollution Heaven Hypothesis (PHH) in selected panel of countries. Institutional quality has a significant negative impact on carbon emissions, while GDP, trade openness, urbanization, and investment in transport infrastructure contribute significantly to carbon dioxide emissions. Country wise estimates of the AMG strategy show that the institutional quality of oil-producing countries has no significant impact on economic growth, but does boost economic growth in non-oil producing countries. The quality of institutions in both non-oil and oil-producing countries can significantly reduce carbon emissions. FDI stimulates economic growth in oil-producing countries compared to non-oil-producing countries. However, FDI contributes significantly to both oil and non-oil-producing CO_2 emissions, thus validating PHH. Controlling factors such as economic growth increase significantly to CO_2 emissions in oil-producing countries, while, CO_2 emissions from petro-states stimulate more to economic growth than non-petroleum states. The impact of trade liberalization on economic growth is significantly positive in both oil and non-oil-producing countries, but the contribution of non-oil-producing economies is higher than that of oil-producing countries. Compared with non-oil producing countries, trade liberalization in oil-producing countries contributes more to carbon emissions. Investment in transportation infrastructure significantly boosted economic growth in both oil and non-oil producing countries, but oil

OPEN ACCESS

EDITED BY
Khurram Shehzad,
Southeast University, China

REVIEWED BY
Edmund Udemba,
Gelişim Üniversitesi, Turkey
Hong-Dian Jiang,
China University of Geosciences, China

*CORRESPONDENCE
Taiming Zhang,
taimingzhang1990@outlook.com

SPECIALTY SECTION
This article was submitted to Environmental Economics and Management,
a section of the journal Frontiers in Environmental Science

RECEIVED 19 October 2022
ACCEPTED 05 December 2022
PUBLISHED 04 January 2023

CITATION
Yang Y, Xu X, Yin J and Zhang T (2023), An empirical analysis of FDI and institutional quality on environmental quality and economic growth, evidence from the panel of asian oil-producing and non-oil-producing economies.
Front. Environ. Sci. 10:1066221.
doi: 10.3389/fenvs.2022.1066221

producing countries contributed more than non-oil producing countries. A range of policy proposals were discussed to achieve economic and environmental sustainability.

KEYWORDS

FDI, institutional quality, economic growth, AMG estimation, oil and non-oil producing countries

1 Introduction

The link between developing economies and environmental protection is complex, as the process of increasing energy use to enhance production results in massive carbon dioxide emissions, which in turn contribute to climate change and threaten human health and the environment (Lenzen et al., 2020). Consequently, the challenges faced by many developing countries in reconciling economic development with environmental protection have been extensively studied in numerous political and academic contexts (Shahzad et al., 2021). Numerous studies have shown that environmental protection and higher economic growth depend to a large extent on the quality of state institutions (Povitkina, 2018; Liu et al., 2021). This is due to the direct or indirect macro-control of the government on environmental protection and economic development. Explicitly, institutional quality is linked to the strategies adopted by domestic institutions to develop the legal and cultural rules on which socioeconomic activities are based. The execution of these policies can shape a government's ability to enforce policies and regulations, demonstrating the quality of public services, the absence of violence, and political stability (Castellacci et al., 2022; Dhaoui, 2022). The most widely accepted element of governance is the rule of law, which is key to addressing environmental issues (Akerboom & Craig, 2022).

China, India, Indonesia and the United Arab Emirates are major oil producers in Asia, and these large economies are resource-rich and attract large inflows of foreign direct investment. However, the most recent non-oil producing economies, South Korea, Singapore, Japan and Bangladesh, have also attracted significant FDI inflows. FDI inflows to Asian economies (both oil-producing and non-oil-producing) make a significant contribution to economic growth and environmental performance, and this relationship clearly demonstrates the importance of institutional quality in selected Asian countries (Kamah et al., 2021).

The impact of FDI inflows on the country's environment and economy cannot be ignored. There is no doubt that FDI can generate capital financing, leverage spillovers, technology transfer, productivity enhancement, and the development of new processes and management capabilities to create positive externalities and boost economic growth (Jiang et al., 2020). Currently, many countries encourage green foreign direct investment with a focus on reducing environmental degradation associated with industrial production and promoting economic growth. Most countries are now encouraging green FDI, which focuses on economic growth while reducing the environmental emissions associated with industrial production (Mohanty & Sethi, 2022; Zafar et al., 2020). However, encouraging FDI inflows can also contribute to the hypothesis of pollution havens (PHHs) by stimulating carbon emissions (Singhania & Saini, 2021; Luo et al., 2022). This hypothesis proposes that developing countries with relatively flexible regulations can provide a comparative advantage for developed countries to invest in pollution-intensive commodity production. Thus, FDI through direct pollution may worsen the environmental quality of developing countries (Majeed et al., 2022). On the contrary, few researchers support the "pollution halo hypothesis", arguing that FDI can improve county environmental quality through substitution effect and technology spillover effect (Karaduman, 2022; Liu et al., 2022). However, some studies have explored the environmental impact of FDI as mixed or insignificant (Xu et al., 2022). Although researchers have uncovered conflicting findings between FDI and the environment. The logical reasoning behind the differences of opinion, due to different national conditions, individual researchers may put forward different opinions. Moreover, researchers differed in measurement models, analytical methods, data selection, and study samples. Thus, the main purpose of this study is to explore the impact of FDI and institutional quality on economic growth and environmental quality in high oil producing countries in Asia (China, India, UAE and Indonesia) and non-oil producing economies (South Korea, Singapore, Bangladesh and Japan) over the Period 1975–2020. The selection of the oil-producing and non-oil-producing economies panel is based on a comparison of the effectiveness results for the two types of economies.

Several studies have used datasets and economies with different explanatory variables to explore factors that influence the environmental growth relationship. This study revolutionizes the relationship of environment and economic growth in terms of explanatory variables and selection of country panels. Hence, this study makes a significant contribution to the existing literature by estimating the links between foreign direct investment, institutional quality, economic growth, and environmental quality in oil-producing countries (China, India, Indonesia and the United Arab Emirates) and non-oil-producing economies (South Korea, Singapore, Japan and Bangladesh). Moreover, the first-generation panel unit root test is not applicable due to cross-sectional dependence data

10.3389/fenvs.2022.1066221

issues, so this study uses the second-generation unit root test proposed by Pesaran (2007) to account for cross-sectional dependence. Long-term cointegration among variables is explored through three cointegration tests by Pedroni (1999, 2004), Kao (1999) and Westerlund (2007). Additionally, the long-term coefficient variable elasticities can be explored using the Augmented Mean Group (AMG) method. Augment Mean Group (AMG) estimation techniques can produce more robust results than traditional methods while overcoming the problems of cross-sectional dependencies and country-specific heterogeneity. Moreover, the main advantage of the AMG estimator can help achieve more adequate policy-oriented goals and provide country-specific results. The Dumitrescu and Harlin (2012) panel causality test in this study can also be used to resolve cross-sectional dependencies.

2 Literature review

2.1 Effects of institutional quality on economic growth and environment

As acknowledged in the institutional economics literature, institutional quality has been one of the most important factors in economic growth since the influential work of Williamson (1989) and North (1990). An institution that implements situational control by developing and regulating rules and regulations in public places (Vanderhorst et al., 2021). In general, institutional quality is related to the strategies that domestic institutions execute to establish the empowering and cultural framework within which socioeconomic events take place. Thus, demonstrate the government's ability to eloquently and politically influence policies and conventions that promote the private sector, property rights protection, improved contract enforcement, strong rule of law, and institutional justice (Hope Sr, 2020). By contrast, when institutions are weak, private sector support is ineffective, leading to bureaucracy, corruption and weak environmental regulation (Bawole & Langnel, 2021; Lakshmi et al., 2021).

Previous literature has clearly demonstrated that institutions play a key role in the formulation and management of economic growth and environmental regulations, which in turn stimulate economic growth and reduce environmental damage. Nair et al. (2021) received data from 67 developing economies for the period 2005–2018 to examine the link between institutional quality, economic growth and CO_2 emissions. The results of the analysis show that institutional quality promotes economic growth and harms carbon emissions in selected economies. Likewise, another recent study by Karim et al. (2022) examines the impact of institutional quality such as corruption control, regulatory quality, and rule of law on carbon emissions and economic growth in 30 sub-Saharan African countries. The findings show that institutional quality (corruption control, regulatory quality, and rule of law) significantly boosts economic growth and reduces carbon emissions. Khan et al. (2021) also explored that environmental quality and economic growth can be enhanced by improving institutional quality and human capital development in seven selected OECD countries. Salman et al. (2019) employed FMOLS and DOLS strategies to estimate the long-term impact of institutional quality on carbon emissions and economic growth for the country panel, Indonesia, South Korea, and Thailand over the period 1990–2016. The results show that institutional quality, energy use, and trade openness promote economic growth. The results also show that institutional quality can significantly reduce environmental damage. Zakaria and Bibi (2019) investigated the effects of financial development and institutional quality on environmental quality in South Asia over the period 1984–2015. The estimation results show that financial development deteriorates environmental quality, while institutional quality improves environmental quality and economic growth. Another study by Ashraf et al. (2022) used panel autoregressive distributive lag (ARDL) to examine the effect of institutional quality on the economic growth-environment relationship in South Asia from 1984 to 2019. The results of the analysis show that an effective and fair political system is essential to simultaneously promote economic development and reduce carbon dioxide emissions. More recently, Ntom Udemba et al. (2022) show that the development of the capacity of government institutions to meet the economic needs of the people has had the greatest impact on mechanisms to curb corruption in West Africa.

Studies have also shown that institutional quality has a significant contribution to carbon emissions. Yang et al. (2022) using the Driscoll Kraay method found that improvements in institutional quality, energy consumption, industrialization, trade openness, and economic development significantly increased CO_2 emissions in 42 developing countries over the period 1984–2016. Obobisa, Chen, and Mensah (2022) investigated the impact of institutional quality, economic growth, and fossil fuel energy consumption on carbon emissions in African countries from 2000 to 2018 using a second-generation panel approach, AMG, and CCEMG estimators. The results of the analysis show that institutional quality, economic growth and fossil fuel energy consumption contribute significantly to CO2 emissions in selected countries. Godil et al. (2020) also explored the significant positive impact of institutional quality and GDP on Pakistan's carbon emissions using the QARDL model and quarterly data from Q1 1995 to Q4 2018. Ulucak (2020) also empirically documented that institutions have a positive impact on environmental degradation in 18 Asia-Pacific Economic Cooperation (APEC) countries in the 1992–2015 data range. Islam et al. (2021) used a dynamic ARDL simulation model in Bangladesh over the period 1972–2016 and explored that institutional quality, as measured by the Political Terrorism

Scale (PTS), reduced environmental quality in both the long and short term. Similarly, another study by Azam et al. (2021) concluded that, using the systematic generalized method of moments (GMM), institutional quality contributes significantly to oil and fossil-based CO_2 emissions, CH_4 emissions, and energy consumption in 66 developing economies.

2.2 Effects of foreign direct investment (FDI) on economic growth and environment

Many studies reveal the link between FDI, economic growth, and the environment from different perspectives, including methodology, sample data selection, and country selection. Several studies have shown that foreign direct investment makes a significant contribution to economic growth. Raza, Shah, and Arif (2021) investigate the impact of FDI on economic growth in OECD countries over the period 1996–2013 by employing a fixed-effects model and generalized method of moments (GMM) estimators. The findings show that FDI has a significant positive impact on economic growth in selected OECD countries. Another study by El Menyari (2021) examines the impact of international tourism and foreign direct investment on Morocco's economic growth during the period 1983–2018 using ARDL methods and causality tests. The results show that non-tourism FDI contributes significantly to economic growth, while tourism FDI has a significant adverse effect on Morocco economic growth. Banday et al. (2021) investigate the relationship between FDI, trade openness, and GDP using ARDL models and Dumitrescu and Hurlin Granger causality tests for BRICS economies over the period 1990–2018. The empirical results show that FDI and trade openness significantly promote long-term economic growth, and there is a bidirectional causal relationship between FDI and economic growth. A non-linear ARDL techniques employed by Sokhanvar and Jenkins (2021) to examine the long-term effects of FDI and tourism specialization on economic growth in Eastonia. The results of the analysis show that, in the long run, Estonia's economic growth rate is positively influenced by the rate of international tourism and foreign direct investment inflows.

The controversy stems from inconsistent conclusions about the environmental impact of FDI from existing research. First, the researchers argue that host countries (usually developing countries) have developed moderate environmental policies to attract foreign investors (developed countries with strict environmental controls) with high pollution emissions and high resource consumption in order to maintain "pollution havens hypothesis (PHH)". FDI transfers environmental pollution to the host country through this mechanism, deteriorating the quality of the environment. Balsalobre-Lorente et al. (2022) contributed in testing the validity of PHH by examining the effect of FDI on carbon emission in BRICS countries during the period 1990–2014. The empirical analysis results significantly demonstrate the positive impact of FDI on carbon emissions, thus validating the PHH of the BRICS countries. Luo et al. (2022) also use AMG, CCEMG, and MG estimators to validate PHHs in China, India, and Singapore through the positive impact of the interaction between FDI and non-renewable energy consumption on carbon emissions over the period 1980–2020. Hadj and Ghodbane (2022) analyzed the moderating effect of governance on the relationship between FDI and CO_2 emissions based on fixed and variable effects models for Golf Cooperation Council (GCC) countries. The moderating effect of governance can stimulate the positive impact of FDI on carbon emissions, thereby validating the PHH of GCC countries. Likewise, Dejellouli et al. (2022) tested PHHs in 20 selected African countries to explore the impact of FDI on environmental degradation over the period 2000–2015 by using pooled mean group, mean group, and dynamic fixed-effects estimates. The results show that FDI contributes significantly to carbon emissions in the long run, confirming the PHH in selected African countries. Similarly, another study by Udemba and Yalçıntaş (2021) uses non-linear and long-run asymmetric cointegration to explore the asymmetric impact of foreign direct investment on environmental pollution in Algeria during the period 1970–2018. The results highlight that positive and negative shocks to FDI can reduce environmental pollution and thus contribute to improving environmental quality. Udemba (2021) explores the impact of FDI and fossil fuels on environmental degradation asymmetrically using non-linear and asymmetric methods, collecting quarterly data for Chile from the first quarter of 1996 to the fourth quarter of 2018. The results show that both positive and negative shocks of FDI and fossil fuels can adversely affect Chile's environmental quality by increasing carbon emissions. Similarly, Udemba and Philip (2022) using the ARDL model and quarterly data for Indonesia from the first quarter of 1990 to the fourth quarter of 2018 shows that foreign direct investment significantly reduces carbon emissions.

In contrast, some researchers support the "pollution halo hypothesis", arguing that FDI brings relatively advanced cleaner production technology and pollution control experience to the host country through technology spillover and substitution effects, thereby improving overall environmental quality. Chen, Paudel, and Zheng (2022) pointed out that using spatial econometrics and threshold effect models, FDI not only promoted China's "energy saving", but also improved China's CO_2 emission efficiency and environmental efficiency, confirming the pollution halo hypothesis. Pradhan et al. (2022) validates pollution halo hypothesis in BRICS countries by exploring the adverse effects of FDI on carbon emissions using FMOLS and DOLS models. Likewise, Ullah et al. (2022) also document that FDI significantly reduces carbon emissions in the long run, using the NARDL model, thus validating China's

10.3389/fenvs.2022.1066221

pollution halo hypothesis. Murshed et al. (2022) also attempt to assess the impact of FDI inflows on sustainability, using an autoregressive distributed lag approach with structural disruptions in Bangladesh over the period 1972–2015. The results of the analysis show that FDI inflows increase the share of renewable electricity output in the total electricity output level, thus supporting the pollution halo hypothesis.

From the above literature, a certain theoretical consensus can be drawn, that is, the impact of institutional quality and FDI on economic growth and the environment is an area worthy of further research. There is limited research, especially for emerging Asian countries, on a unified research framework that integrates institutional quality and FDI with the economy and the environment. Thus, this study splits emerging Asian countries into oil-producing and non-oil-producing countries, and adopts the Augmented Average Group (AMG) method to explore the impact of institutional quality and FDI on economic growth and environmental quality.

3 Empirical methods

3.1 Theoretical framework

The main factors that determine the sustainable development of a country's economy and environment are institutional quality and foreign direct investment. Thus, a theoretical link among these variables is crucial to elucidate it.

First of all, the new theory of institutional economics points out that the key factor determining a country's economic growth is the quality of the institution (Shleifer & Vishny, 1993). A country's performance is directly affected by institutional trends, rational underlying institutions, institutional structure, and institutional environment. The economic growth potential of most developing countries is hampered by weak and inefficient institutions and corruption. The capital circular accumulation theory cannot explain the long-term low-growth trap in less developed countries that Myrdal and Sitohang (1957) recognized when discussing the impact of institutional factors on developing countries. North (1990) proposed that institutions play a decisive role in economic development in terms of population and savings, and institutions are a series of rules of the game. Like other physical resources, institutional quality can be high or low. A high-quality system can effectively improve the efficiency of resource allocation and promote economic growth, which is also a country's comparative advantage However, at different levels of development, institutions have different impacts on countries.

At the same time, institutional quality affects environmental conditions in many ways, because it reflects the overall development environment and conditions of a country. Reasonable institutional arrangements can effectively promote the utilization and allocation of national resources, and this higher resource allocation can significantly promote environmental quality (Teng et al., 2021).

Secondly, the contribution of foreign direct investment to national economic growth has generally replicated the stimulating effect of foreign direct investment on economic growth in terms of capital, labor, technology and other inputs. Rostow (1990) believed that capital accumulation is the key variable for developing countries to get rid of the difficulty of economic backwardness during the take-off stage. Solow (1956) in his neoclassical growth model, if the exogenous factors of technology and *per capita* income level are held constant, the economy will move towards a steady-state equilibrium. Lucas (1988) and Romer (1986) proposed that under the framework of the new growth theory, factors such as human resource capital and knowledge are endogenous. Thus, the productivity of capital can increase or remain unchanged, and the output *per capita* must theoretically increase as well. In addition, FDI affects economic growth in different ways, especially FDI solves the problem of capital shortage in the process of economic development of the host country, stimulates the development vitality of enterprises, and relieves the pressure on banks.

At the same time, the country's environment will also be affected by FDI, so FDI affects environmental quality through various methods such as scale, structure, and technical effects (Hao et al., 2020; Jiang et al., 2022; Jiang et al., 2022; Wang et al., 2022; Zafar et al., 2020). The increase in pollution discharge is the result of the expansion of production scale, which reflects the scale effect. Structural effects are mainly manifested in the fact that most developing countries are actively promoting the process of industrialization, and most of the imported foreign capital flows into industries with high pollution emissions and high energy consumption, causing adverse structural impacts on the environment. Environmental quality in developing countries cannot be improved by this process. Finally, the role of technology is mainly reflected in the improvement of FDI, which drives the country economic development. It also produces technological spillovers to the host country through imitation, demonstration and association effects to expand its environmental quality, technological level and production capacity.

3.2 Model development

In a deep link to the above theoretical background, we highlight the specification of the following two econometric models to examine the impact of FDI inflows and institutional quality on economic growth and carbon emissions in oil and non-oil producing countries.

$$GDP_{it} = f(FDI_{it}, IQ_{it}, CO_{2it}, TO_{it}, TINF_{it}, URB_{it}) \quad (1)$$

$$CO_{2it} = f(FDI_{it}, IQ_{it}, CO_{2it}, TO_{it}, TINF_{it}, URB_{it}) \quad (2)$$

GDP is gross domestic product as a proxy for economic growth, with FDI for foreign direct investment, IQ denotes institutional quality, CO_2 indicates carbon dioxide emission, TINF stands for

TABLE 1 Description, measurement and data sources of variables.

Variables	Description	Measurment	Sources
CO_2	Carbon dioxide Emission	Million metric tons (Mmt),	WDI, World Bank
GDP	Gross Donestic Product	Constant 2015 US$	WDI, World Bank
TINF	Transport infrastructure investment	Constant 2015 US$	OECD database
URB	Urbanization	Percentage of total population	WDI, World Bank
IQ	Institutional quality	Institutional quality index	Heritage Economic Freedom Index
TO	Trad openness	Percentage of GDP	WDI, World Bank
FDI	Foreign direct investment	Percentage of GDP	WDI, World Bank

transport infrastructure investment, URB represents urbanization and μ is the model error term reflecting a stochastic process. The above models are transformed into a log-linear form for empirical analysis as follows:

$$\ln GDP_{it} = \beta_0 + \beta_1 \ln FDI_{it} + \beta_2 \ln IQ_{it} + \beta_3 \ln CO_{2it} + \beta_4 \ln TO_{it} + \beta_5 \ln TINF_{it} + \beta_6 \ln URB_{it} + \mu_{it} \quad (3)$$

$$\ln CO_2 it = \beta_0 + \beta_1 \ln FDI_{it} + \beta_2 \ln IQ_{it} + \beta_3 \ln GDP_{it} + \beta_4 \ln TO_{it} + \beta_5 \ln TINF_{it} + \beta_6 \ln URB_{it} + \mu_{it} \quad (4)$$

Where β_0 is the intercept, $\beta_{1\text{-}6}$ are the coefficients of variables, and i and t represent countries and periods, respectively.

3.3 Variable descriptions, measurements and data sources

Annual data for all variables for the period 1975–2020 are from the World Bank, World Development Indicators (WDI) database, transport infrastructure investment data from the OECD database and institutional quality data from the Heritage Economic Freedom Index. All variables used for smoothing purposes have been converted to natural logarithmic form. Carbon emissions, the explained variable used in this study for environmental degradation, is measured in millions of metric tons (Mmt). GDP (representing economic growth) is another dependent variable, and investment in transport infrastructure is the explanatory variable, measured in constant 2015 dollars. Foreign direct investment and trade openness are controlled factors, measured as a percentage of GDP. Urbanization is another control variable measured as a percentage of the total population. Institutional quality is based on 12 quantitative and qualitative components of economic freedom, grouped into four pillars, namely rule of law, regulatory efficiency, open markets, and size of government. See Table 1 for full details of variable descriptions, measurements, and data sources.

TABLE 2 Results of cross-sectional dependency test.

	Model-GDP		Model-CO_2	
Test	Statistics	Prob	Statistics	Prob
Breusch-Pagan LM	755.68***	0.000	833.53***	0.001
Pesaran scaled LM	66.79***	0.001	73.22***	0.003
Bias-corrected scaled LM	65.36***	0.004	73.09***	0.000
Pesaran CD	5.29***	0.003	0.982**	0.002

*, **, *** indicate statistical significance levels of 10%, 5%, and 1%, respectively.

3.4 Cross sectional dependence test

It is crucial before using the unit root properties of variables to determine the cross-sectional dependence of panel data, followed by the prevailing panel cointegration and panel variable coefficient elasticity estimation methods. Panel data estimates with cross-sectional dependence can lead to bias, error, and misleading (Awad & Warsame, 2022; Rodríguez-Caballero, 2022). The cross-sectional dependence test proposed by Breush and Pegan (1980), used by several previous studies, raises several econometric questions. Thus, to overcome the shortcomings of previous methods, this study uses the more robust cross-sectional dependence (CD) test and Langrage multiplier (LM) test introduced by Hashem (2021). Below are the respective CD and LM test equations.

$$CD = \sqrt{\left(\frac{2\rho}{\kappa(\kappa-1)}\right)}\left(\sum_{i=1}^{\kappa-1}\sum_{j=i+1}^{\kappa}\hat{T}_{ij}\right):\ \kappa\,(0,1) \quad (5)$$

$$LM^* = \sqrt{\left(\frac{2\rho}{\kappa(\kappa-1)}\right)}\left(\sum_{i=1}^{\kappa-1}\sum_{j=i+1}^{\kappa}\hat{T}_{ij}\right)\frac{(\rho-n)\hat{\rho}_{ij}^2 - E(\rho-n)\hat{\rho}_{ij}^2}{Var(\rho-n)\hat{\rho}_{ij}^2} \quad (6)$$

Table 2 below shows the results of the cross-sectional dependence test, which clearly shows coefficients that are highly significant at the 1% significance level. The results of both models confirmed the cross-sectional dependence of the selected sample data.

10.3389/fenvs.2022.1066221

TABLE 3 Findings of the panel unit root tests.

Variables	Lcc		IPS		ADF-Fisher		PP-Fisher		CADF		CIPS	
	C	C + T	C	C + T	C	C + T	C	C + T	C	C + T	C	C + T
$InCO_2$	−1.95**	−2.18	0.21	−0.29*	31.27	24.31	213.21	12.23	0.21	0.36	−1.27	−0.24
InFDI	1.66	3.13	0.24	2.14	24.37	63.24	256.32	13.25	0.29	0.28	−1.53	−1.29
InGDP	1.55	4.12	1.26	3.21	17.29	52.14	93.21	14.24	1.26	1.63	−1.74	−2.17
InURB	5.26***	-0.21	−2.43	4.65	19.82	26.72	97.32	15.37	2.74	2.38	−1.89	−1.26
InTO	−0.26	−0.35	−3.21	−3.24	34.82	28.36	83.72	19.14	3.28	3.28	−0.29	−0.62
InTINF	−4.72	−0.25	−4.29	−5.21	29.37	17.92	71.27	23.24	−6.27	−3.28	−0.59	−0.37
InIQ	−4.49	−2.9	−3.47	−0.45	47.28	5.32	69.81	25.26	−5.32	2.15	−1.58	−1.28
$\Delta InCO_2$	-2.73***	-3.21***	-2.13***	-2.15***	121.27**	134.32**	58.25***	25.29***	-0.26***	-1.27***	-1.93***	-1.27***
ΔInFDI	-3.21***	-4.21***	-3.21***	-0.26***	23.21***	213.21**	26.36***	28.13**	-1.27**	-1.28***	-1.49***	-0.18**
ΔInGDP	-1.24***	-0.23***	-5.32**	-1.26***	19.26***	21.34***	72.16**	29.27***	-2.17***	-2.16***	-0.28***	-1.58***
ΔInURB	-8.30***	-7.32***	-3.21***	-1.32***	15.27***	49.32***	27.37**	42.26***	-2.17***	-3.21***	-0.26***	-1.26***
ΔInTO	−3.98***	−4.19	−5.32***	−0.73***	31.25**	21.25***	38.48***	48.29**	−3.27***	−0.27**	−1.27**	−1.36***
ΔInTINF	−4.28***	−2.63**	−2.14**	−0.27***	37.28***	93.21***	92.14***	59.37***	−4.21***	−1.76***	−0.21***	−1.52**
ΔInIQ	−6.39***	−3.21***	−3.14***	−1.25***	28.29***	83.25***	82.37***	62.28***	−0.29***	−1.59***	–	–

*, **, *** denote significance levels of 10%, 5%, and 1%, respectively, C stands for constant and C + T denotes for constant and trend.

3.5 Panel unit root test

The first-generation panel unit root test is not applicable due to cross-sectional dependence data issues, so we used the second-generation unit root test proposed by Pesaran (2007) to account for cross-sectional dependence. Below is the expression of the underlying equation for each variable z_{it}:

$$z_{it} = (1 - \lambda_i)\varepsilon_i + \varepsilon_i z_{i,t-1} + \varepsilon_{it}, i = 1, \ldots\ldots, K; t = 1, \ldots\ldots, N \quad (7)$$

where the error term e_{it} can be specified as an unobserved common factor f_t function.

$$\varepsilon_{it} = \rho_i f_t + \mu_{it} \quad (8)$$

where e_{it} represents a country-specific factor, so we transform Eq. 7 to get the following equation.

$$\Delta z_{it} = \beta_i + \alpha_i z_{i,t-1} + \rho_i f_t + \mu_{it} \quad (9)$$

Thus, the following is the expression for the cross-sectional augmented Dicky-Fuller (CADF) panel unit root test

$$\Delta z_{it} = \beta_i + \alpha_i z_{i,t-1} + d_i \Delta \bar{z}_t + \mu_{it} \quad (10)$$

The null hypothesis of no stationarity associated with each series in Eq. 10 determines the integration order based on the OLS estimator αi. Furthermore, the mathematical expression of the CADF t statistic is represented by the following Eq. 11.

$$t_t(K, T) = \frac{\Delta y_i' \bar{M}_w z_{i,-1}}{\hat{\sigma}_i (y_i' \bar{M}_w z_{i,-1})^{1/2}} \quad (11)$$

The generalized equation form above has been transformed into the following specific case, but to determine critical values, simulations are required.

$$\text{CIPS}(K, T) = \bar{t} = K^{-1} \sum_{i=1}^{K} t_i(K, T) \quad (12)$$

The results of the panel unit root test, shown in Table 3, clearly show that all variables are transformed to be stationary at the first derivative and have integral order I (1). This fact further allows us to use panel cointegration and panel ARDL estimation.

3.6 Panel cointegration test

The next step is to apply the state-of-the-art technique of Westerlund (2007) to determine the cointegration relationship between series after examining cross-sectional dependence and unit root issues. This test is an error-correcting cointegration test that allows for cross-sectional dependence problems. The test is based on structure rather than residual kinetics, which is a distinguishing feature of the method and is therefore not affected by unobserved common factors (Shah et al., 2020; Chen et al., 2021). The econometric model of Westerlund's (2007) cointegration test is expressed as follows.

$$\Delta Z_{it} = \delta_i' d_t + \beta_i z_{it-1} + \lambda_i' y_{it-1} + \sum_{j=1}^{Ki} \beta_{ij} \Delta v_{it-j} + \sum_{j=1}^{Ki} \lambda_{ij} \Delta x_{it-j} + \varepsilon_{it} \tag{13}$$

β_i in the above Equation 17 is the adjustment speed, which determines the adjustment of long-term fluctuations after short-term imbalances. Westerlund (2007) developed four tests to determine cointegration, the first two of which are called group mean statistics and are expressed as follows.

$$G_t = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{\beta}_i}{SE(\hat{\beta}_i)} \tag{14}$$

$$G_\beta = \frac{1}{N} \sum_{i=1}^{N} \frac{T\hat{\beta}_i}{\hat{\beta}_i(1)} \tag{15}$$

If the two tests are found to be statistically significant, the null hypothesis that there is no cointegration relationship between the variables in the entire panel can be rejected. Statistics from the other two panels determine to explore cointegration in at least one country.

$$P_t = \frac{\hat{\beta}_i}{SE(\hat{\beta}_i)} \tag{16}$$

$$P_\beta = T\hat{\beta}_i \tag{18}$$

3.7 Long-term elasticity estimation

After establishing long-term panel cointegration, panel dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) may be the best options for determining long-term variable elasticity, but FMOLS and DOLS strategies ignore cross-sectional dependencies (Rahman et al., 2021). Econometric models are subject to cross-sectional dependencies and country-specific heterogeneity, which can lead to biased or misleading inferences (Simionescu & Schneider, 2022). Thus, the Augmented Mean Group (AMG) method proposed by Eberhardt and Bond (2009) and Teal & Eberhardt (2010). Can produce more robust results than traditional methods while overcoming these problems. The main advantage of the AMG estimator can help achieve more adequate policy-oriented goals and provide country-specific results. The AMG estimation functional form is contained in a two-stage process and can be expressed in equations (9) and (10) as follows:

$$\Delta Z_{it} = \beta i + \rho_i \Delta x_{it} + \kappa_i g_t + \sum_{t=2}^{T} \alpha_i \Delta h_t + \varepsilon_{it} \tag{19}$$

$$\hat{\beta}_{AMG} = N^{-1} \sum_{t=2}^{T} \hat{\beta}_i \tag{20}$$

Where βi is the intercept, Z_{it} and X_{it} represent observed factors and ρi is the cross sectional coefficient estimator. Gt shows the unobserved factors with heterogeneous dynamics, α_i represents the dummy coefficient of time. Moreover, $\hat{\beta}_{AMG}$ indicates the augmented mean Group (AMG) estimator and e_{it} expresses the error term.

3.8 Country-specific analysis using augmented mean groups (AMGs)

Following the study by Yang et al. (2021), this study also uses the Augmented Mean Group (AMG) developed by Teal and Eberhardt (2010) to explore the non-linear effects of urbanization routes on environmental degradation in individual countries. AMG is a panel autoregressive distributed lag (ARDL) model that outperforms first-generation panel ARDL techniques by allowing for cross-sectional dependence and sample heterogeneity (Murshed et al., 2021; Gyamfi et al., 2022). This technique addresses cross-sectional dependencies by incorporating common dynamic effects (CDEs) into a two-stage estimation process (Dogru et al., 2021; Maza, 2022). Furthermore, there are no prerequisites for non-stationary series and cointegration of variables in this technique (Hu, 2021). Thus, AMG method based on these salient features are best suited to examine the national-level impacts of urbanization routes on environmental degradation in the form of first-order differences.

3.9 Granger estimation of causality

Careful examination of causal relationships between correlated variables is also critical for policy advice and formulation. Therefore, this study also adopted the Granger causality test of Dumitrescu and Hurlin (2012) to explore one-way or two-way causality between variables. Compared to traditional VECM, this technique is more robust and applicable because it works with small samples and simultaneously addresses the econometric issues of sample heterogeneity and cross-sectional dependence (Hashemizadeh, Bui, & Kongbuamai, 2021; Azam et al., 2021).

Following the work of Aladejare (2022), Saud, Chen, and Haseeb (2020), this study uses the Heterogeneous Dumitrescu and Hurlin (DH) causality approach with the reverse causality problem as an additional robustness measure. The Dumitrescu and Hurlin (DH) model can be expressed as follows:

$$Z_{i,t} = \beta_i + \sum_{i=1}^{K} \rho_i^{(K)} z_{i,t-n} + \sum_{i=1}^{K} \alpha_i^{(K)} y_{i,t-n} + \varepsilon_{i,t} \tag{21}$$

10.3389/fenvs.2022.1066221

TABLE 4 Panel descriptive statistics and correlation analysis.

Variables	Average	SD	Max	Min	lnCO$_2$	lnEIN	lnGDP	lnURB	lnUAG	lnLCR	lnIND	lnTII	VIF
lnCO$_2$	8.613	4.218	23.725	14.648	1								
lnFDI	0.548	1.441	1.182	0.382	-0.655	1							4.22
lnGDP	1,084.141	597.327	1,628.3	254.326	0.982	-0.898	1						4.71
lnURB	37.601	11.327	19.254	45.321	0.828	-0.739	0.264	1					4.42
lnTO	21.38	4.216	29.365	11.253	-0.151	-0.932	0.473	0.814	1				2.36
lnTINF	25.385	8.915	35.269	19.265	-0.356	-0.372	0.591	0.629	-0.974	1			2.83
lnIQ	41.381	16.283	59.325	24.216	0.392	-0.382	0.712	0.835	-0.382	0.732	1		2.42

SD, denotes standard deviation; VIF, indicates variance inflation factor, Max and Min are maximum and minimum values respectively.

Where ? and y are variables pair-wise combinations, n represent the maximum lag length, i is cross section and t indicate time. $\rho_i^{(K)}$ and $\alpha_i^{(K)}$ represent the sample country coefficients in the regression. The null and alternative hypotheses of the DH model can be expressed as follows:

Null hypothesis → H0 = α_i = 0.

Alternative hypothesis → H1 = $\alpha_i \neq 0$, where ∀i = 1, 2 . . . . . . N and ∀i = N + 1, N + 2... . .N.

4 Analysis results and discussion

First, the descriptive statistics in Table 4 show that the average GDP of the selected countries is $1,084.141 billion, and shows the large change represented by its standard deviation over the period 1975–2020. Carbon dioxide emissions from these Asian countries averaged 8.613 billion metric tons, with a range of 23.725 to 14.648 billion metric tons. The average urbanization rate is 37.60%, reflecting that more than one-third of urban residents live in urban areas. The average foreign direct investment is 0.548%, indicating that the value of foreign investment is equivalent to 54% of GDP. The average investment in transportation infrastructure, institutional quality and trade openness stood out at 25.383 billion US dollars, 41.381% and 21.38% respectively. Correlation coefficient and variance inflation factor (VIF) for each variable to check for multicollinearity issues in the models shown in Table 4. The results show that the model does not suffer from multicollinearity problems, as all values of VIF are below 5.

The panel unit root results clearly show that all variables have an integral property of I (1), allowing the use of panel cointegration tests. The panel cointegration test results of the two models based on GDP and carbon emission are shown in Table 5. The current study used two panel cointegration tests, the Westerlund (2007) test and the Pedroni (1999) panel cointegration test benchmark, to explore the cointegration relationship among variables. Given these two different models, both the Westerlund and pedroni panel tests reject the null hypothesis of no cointegration because both group and panel statistics are significant at the 1% level. Thus, all variables in the proposed models are cointegrated.

Table 6 reports the results of the long-term estimated parameters in the proposed model of Eqs 3, 4. AMG's estimates of variable elasticity based on the GDP model show that for every 1% increase in FDI, institutional quality and carbon emissions can significantly boost economic growth by 0.882%, 0.659%, and 0.605%, respectively. The progressive effect of FDI on economic growth is very consistent with Uzair Ali et al. (2022); Sinha and Sengupta (2022); Iqbal, Tang and Rasool (2022); Wei, Mohsin and Zhang (2022); Luo et al. (2022); Raza, Shah, and Arif (2021). Likewise, the positive effect of institutional quality on economic growth results is consistent with Ashraf et al. (2022); Zakari and Khan (2022); Ashraf et al.

TABLE 5 Results of Westerlund (2007) and Pedroni (1999) Panel Cointegration tests.

Westerlund test			Pedroni test		
GDP-model					
	Statistics	*p*-value		Statistics	*p*-value
Gt	-4.356***	0.03	Panel v-Statistic	-2.881	0.866
Ga	-9.573	0.583	Panel rho-Statistic	0.278	0.678
Pt	-8.506***	0.000	Panel PP-Statistic	-3.446***	0.006
Pa	-9.967	0.497	Panel ADF-Statistic	-4.314***	0.000
			Group rho-Statistic	0.678	0.826
			Group PP-Statistic	-2.985***	0.000
			Group ADF-Statistic	-3.621***	0.000
CO_2-model					
	Statistics	*p*-value		Statistics	*p*-value
Gt	-4.467***	0.001	Panel v-Statistic	-3.991	0.977
Ga	-11.681***	0.002	Panel rho-Statistic	-0.389	0.789
Pt	-10.617***	0.000	Panel PP-Statistic	-3.557***	0.001
Pa	-9.826	0.508	Panel ADF-Statistic	-4.425***	0.000
			Group rho-Statistic	0.483	0.937
			Group PP-Statistic	-2.831***	0.000
			Group ADF-Statistic	-3.732***	0.000

*,**,*** denote statistical significance at the 10%, 5% and 1% levels.

(2022); Wang et al. (2022); Karim et al. (2022); Salman et al. (2019); Zakaria and Bibi (2019). Findings on the driving role of carbon emissions on economic growth are very consistent with You, Zhang and Lee (2022); Espoir et al. (2022); Rehman et al. (2022); Inal et al. (2022) and Ge et al. (2022). Similarly, trade liberalization, transportation infrastructure and urbanization can significantly boost economic growth by 0.605%, 0.417%, and 0.985%, respectively.

Long-term variable elasticity coefficients based on carbon emission model show that a 1% increase in FDI can stimulate a 0.614% increase in carbon emissions, thus validating the Pollution Heaven Hypothesis (PHH). This result is consistent with the studies by Khan, Weili and Khan (2022); Balsalobre Lorente et al. (2022); Azam and Raza, A. (2022); Djellouli et al. (2022); Apergis, Pinar and Unlu (2022). The institutional quality coefficient is 0.717, reflecting that every 1% increase in institutional quality can significantly reduce carbon emissions by 0.717%. This result is consistent with the study by Jahanger et al. (2022); Jiang et al. (2022); Khan et al. (2022); Anwar, Chaudhary and Malik (2022); Sun et al. (2022); Ashraf et al. (2022). For every 1% increase in GDP, trade openness, urbanization and transportation infrastructure investment, carbon dioxide emissions increased significantly by 0.736%, 0.705%, 0.325% and 0.821%, respectively.

Country-wise estimation results by the AMG strategy are reported in the following Table 7. Emerging Asian countries are divided into oil-producing countries (China, India, UAE and Indonesia) and non-oil-producing countries (South Korea, Singapore, Bangladesh and Japan) to see whether FDI and institutional quality show heterogeneity in terms of economic growth and environmental quality. The results show that the institutional quality of oil-producing countries has no significant impact on economic growth, but it does promote economic growth in non-oil-producing countries. Thus, for every 1% increase in institutional quality, the economic growth of non-oil producing countries can increase significantly by 0.532%. For every 1% increase in institutional quality, the carbon dioxide emissions of non-oil-producing countries and oil-producing countries decreased by 0.931% and 0.198%, respectively. This suggests that integrating institutions, especially in areas such as regulatory efficiency, open markets, size of government, and the rule of law, can reduce carbon dioxide emissions and improve environmental quality. Furthermore, the inhibitory effect of the regime on emissions is higher in non-oil-producing economies than in oil-producing economies. Foreign direct investment stimulates economic growth in oil-producing countries compared to non-oil-producing countries. The results show

TABLE 6 Results of the panel AMG method for estimating parameters, $lnGDP_{it}=f(lnFDI_{it}, lnIQ_{it}, lnCO_{2it}, lnTO_{it}, lnTINF_{it}, lnURBit)$.

	MG		AMG		CCEMG	
Variables	Coeff	*p*-value	Coeff	*p*-value	Coeff	*p*-value
$lnFDI_{it}$	0.534***	(0.000)	0.882***	(0.003)	0.281***	(0.000)
$lnIQ_{it}$	0.714***	(0.001)	0.659***	(0.005)	0.629***	(0.003)
$lnCO_{2,it}$	-0.465***	(0.004)	0.605***	(0.006)	0.372***	(0.000)
$lnTO_{it}$	0.832**	(0.042)	0.605*	(0.002)	0.183*	(0.052)
$lnTINF_{it}$	0.735*	(0.053)	0.417**	(0.004)	0.391*	(0.061)
$lnURB_{it}$	0.371**	(0.048)	0.985***	(0.002)	0.723*	(0.053)
$lnCO_{2it}=f(lnFDI_{it}, lnIQ_{it}, lnGDP_{it}, lnTO_{it}, lnTINF_{it}, lnURB_{it})$						
	MG		AMG		CCEMG	
Variables	Coeff	*p*-value	Coeff	*p*-value	Coeff	*p*-value
$lnFDI_{it}$	0.647***	(0.003)	0.614***	(0.000)	0.318**	(0.032)
$lnIQ_{it}$	-0.659***	(0.000)	-0.717**	(-0.031)	-0.413***	(0.000)
$lnGDP_{it}$	0.848***	(0.002)	0.736***	(0.003)	0.328***	(0.002)
$lnTO_{it}$	0.658***	(0.002)	0.705***	(0.000)	0.327	(0.213)
$lnTINF_{it}$	0.284*	(0.064)	0.821*	(0.051)	0.812***	(0.000)
$nURB_{it}$	0.246**	(0.042)	0.325**	(0.023)	0.425**	(0.031)

***, ** and * indicate statistical significance at 1% level, 5% level and 10% level respectively, where inside.

TABLE 7 Country-specific analysis results estimated by the AMG method.

Variables	Oil producing countries		Non-oil producing countries	
	$lnGDP_{it}$	$lnCO2_{it}$	$lnGDP_{it}$	$lnCO2_{it}$
$lnGDP_{it}$	-----	0.0.321*** (0.009)	------	0.362 (0.352)
$LnC\ O\ 2,\ it$	0.662*** (0.000)	--------	0.382*** (0.006)	------
lnFDIit	0.513** (0.042)	0.865** (0.043)	0.343*** (0.007)	0.532** (0.032)
LnIQit	0.574 (0.142)	−0.198*** (−0.001)	0.532*** (0.005)	−0.931 (−0.372)
lnTOit	0.341*** (0.000)	0.543** (0.044)	0.712* (0.063)	0.153* (0.052)
LnTINF	0.574*** (0.002)	0.727* (0.002)	0.387*** (0.001)	0.482** (0.032)
lnURBit	*0.524*** (0.000)*	*0.216** (0.021)*	*0.712*** (0.000)*	*0.421** (0.041)*

***, ** and * indicate statistical significance at 1% level, 5% level and 10% level respectively, where inside. where inside in the parenthesis are probability values.

that for every 1% increase in foreign direct investment, the economy of oil-producing countries can increase by 0.513%, and the economy of non-oil-producing countries can increase by 0.343%. The comparison between non-oil-producing countries and oil-producing countries shows that the latter is rich in oil resources, which can improve the production enthusiasm of enterprises and reduce production costs. Abundant oil resources are an important factor in attracting foreign investment and promoting economic growth. However, FDI contributes significantly to both oil-producing and non-oil-producing CO2 emissions, thus validating PHH. The impact coefficient of FDI on CO2 emissions in oil-producing countries is higher than that in non-oil-producing countries, reflecting that FDI is based on non-clean technologies has a higher degree of

10.3389/fenvs.2022.1066221

TABLE 8 Results of Dumitrescu and Hurlin pairwise causal relationships between variables in the proposed model.

Direction of causality	W-Stat	Zbar-Stat	Probability
lnFDI → lnCO$_2$	4.946***	2.661***	0.01
lnCO$_2$ → lnFDI	3.151***	2.639***	0.00
lnGDP → lnCO$_2$	4.173	1.845**	0.02
lnCO2 → lnGDP	3.859	2.462	0.53
lnIQ → lnCO$_2$	2.744***	1.561***	0.00
lnCO2 → lnIQ	1.072***	4.578**	0.03
lnTO → lnCO$_2$	2.691***	1.659***	0.01
lnCO$_2$ → lnTO	3.629**	1.462**	0.03
lnTINF → lnCO2	1.076***	-1.633***	0.00
lnCO2 → lnTINF	3.613	2.422	0.42
lnURB → lnCO$_2$	1.391	2.185	0.37
lnCO2 → lnURB	2.152	1.729	0.28
lnFDI → lnGDP	1.028	1.823	0.91
lnGDP → lnFDI	2.183***	2.183***	0.00
lnIQ → lnGDP	1.731**	3.174**	0.02
lnGDP→lnIQ	2.190	1.801	0.72
lnTO → lnGDP	3.215	1.823	0.53
lnGDP→ lnTO	1.892***	1.868***	0.00
lnTINF→ lnGDP	1.320	1.237	0.53
lnGDP→ lnTINF	1.561***	1.692***	0.00
lnURB→lnGDP	2.194	1.734	0.38
lnGDP→lnURB	1.265	1.287	0.21

*,**,*** denote statistical significance at the 10%, 5% and 1% levels.

deterioration of environmental quality in oil-producing countries than in non-oil-producing economies.

Controlling factors such as economic growth will only increase CO2 emissions in oil-producing countries. Specifically, 1% economic growth can increase the carbon dioxide emissions of oil-producing countries by 0.321%. Moreover, CO2 emissions from petro-states contribute more to economic growth than non-petroleum states. This may be because oil-producing countries have more economic activity than non-oil-producing countries, and therefore consume a higher proportion of fossil fuel carbon emissions. The impact of trade liberalization on economic growth is significantly positive in both oil-producing countries and non-oil-producing countries, but the contribution of non-oil-producing economies is higher than that of oil-producing countries. Compared with non-producing countries, trade liberalization in oil-producing countries contributes more to carbon emissions. Transportation infrastructure investment significantly boosted economic growth in both oil and non-oil producing countries, but oil producing countries contributed more than non-oil producing countries. Similarly, comparing the impact of transportation infrastructure investment on carbon emissions, the progressive effect of transportation infrastructure investment on carbon emissions in oil-producing countries is higher than that in non-oil-producing countries. Urbanization leads to higher levels of economic growth in non-producing countries compared to oil-producing countries. Therefore, higher levels of urbanization can immediately activate the economy and promote economic growth. Likewise, urbanization also leads to higher CO2 emissions in non-oil producing countries compared to oil-producing countries.

The next step is to use Dumitrescu and Hurlin (2012) to examine the pairwise causal relationship between variables in the proposed models. The causality test provides causality results for selected variables in Table 8, accounting for panel heterogeneity. The causality test results clearly identified a bidirectional causal relationship between FDI and carbon dioxide emissions, institutional quality and carbon emission, trade openness and carbon emission. The results also show one-way causality from transport infrastructure investment to carbon emissions, GDP to FDI, institutional quality to GDP, GDP to trade openness, and GDP to transport infrastructure investment.

5 Conclusion and policy recommendations

The attractiveness of FDI and the effectiveness of institutional implementation in controlling economic growth and improving environmental quality are currently hot topics of debate among scholars. In this context, this study uses the AMG estimation technique to examine whether FDI and institutional quality affect economic growth and environmental quality in eight emerging Asian countries from 1975 to 2020. For comparative analysis, emerging Asian countries are divided into oil-producing and non-oil-producing countries. AMG's estimates of variable elasticity based on GDP models suggest that foreign direct investment, institutional quality, and carbon emissions can contribute significantly to economic growth in the long run. Likewise, trade liberalization, transport infrastructure and urbanization can significantly boost economic growth. Long-term variable elasticity coefficients based on carbon emissions models suggest that FDI can stimulate carbon emissions, thereby validating the Pollution Heaven Hypothesis (PHH) in selected panel of countries. Institutional quality has a significant negative impact on carbon emissions, while GDP, trade openness, urbanization, and investment in transport infrastructure contribute significantly to carbon dioxide emissions. Country-by-country estimates of the AMG strategy show that the institutional quality of oil-producing countries has no significant impact on economic growth, but does boost economic growth in non-producing countries. The quality of institutions in both non-oil producing and oil-producing countries can significantly reduce carbon emissions. Moreover, foreign direct investment stimulates economic growth in oil-producing countries compared to non-oil-producing countries. However, FDI contributes significantly to both oil-producing and non-oil-producing CO_2 emissions, thus validating PHH. The impact coefficient of FDI on CO_2 emissions in oil-producing countries is higher than that in non-oil-producing countries, reflecting that FDI is based on non-clean technologies has a higher degree of deterioration of environmental quality in oil-producing countries than in non-oil-producing economies. Controlling factors such as economic growth will only increase CO_2 emissions in oil-producing countries, while, CO_2 emissions from petro-states contribute more to economic growth than non-petroleum states. The impact of trade liberalization on economic growth is significantly positive in both oil-producing countries and non-oil-producing countries, but the contribution of non-oil-producing economies is higher than that of oil-producing countries. Compared with non-producing countries, trade liberalization in oil-producing countries contributes more to carbon emissions. Transportation infrastructure investment significantly boosted economic growth in both oil and non-oil producing countries, but oil producing countries contributed more than non-oil producing countries. Similarly, comparing the impact of transportation infrastructure investment on carbon emissions, the progressive effect of transportation infrastructure investment on carbon emissions in oil-producing countries is higher than that in non-oil-producing countries. Urbanization leads to higher levels of economic growth in non-producing countries compared to oil-producing countries. Likewise, urbanization also leads to higher CO_2 emissions in non-oil producing countries compared to oil-producing countries. The pairwise causality results of Dumitrescu and Hurlin (2012) suggest that there are bidirectional causality between FDI and carbon dioxide emissions, institutional quality and carbon emissions, and trade openness and carbon emissions. Moreover, the results also show one-way causality running from transport infrastructure investment to carbon emissions, GDP to FDI, institutional quality to GDP, GDP to trade openness, and GDP to transport infrastructure investment.

Important policy implications can be drawn from the empirical findings of this study. First, system construction is essential to promote economic development and environmental quality. Thus, it is important to strengthen institutions, especially those that improve regulatory efficiency, build the rule of law, and expand open markets and the size of government. These institutional quality indicators can effectively condense the adverse effects of other institutional problems and official corruption, and promote sustainable development. Emerging oil-producing countries in Asia should establish a strong system to exert its effectiveness and reduce pollution without affecting the long-term stable development of its economy. Moreover, strong institutional quality can improve the efficiency of environmental regulation and can generate demand for better environmental standards. Thus, local governments should build strong institutions and low pollution emissions by raising public awareness. Improvements in institutional quality in the short or long term can promote environmental quality and accelerate economic development. Improving and regulating the role and efficiency of domestic institutions can lead to future green and sustainable growth for non-oil-producing emerging countries in Asia, a direct message to policymakers.

Second, oil-producing and non-oil-producing countries should look to accelerate technology and capital spillovers through foreign investment to boost economic development, and use clean-tech FDI to improve energy efficiency and reduce pollution. The high-quality inflow of foreign direct investment will be realized by improving the foreign investment introduction policy and promoting the supervision system and other related measures. Third, improving transportation infrastructure in oil-producing and non-oil producing countries can lead to green, environmental protection, and energy-saving investments. Fourth, both oil-producing countries and non-oil-producing countries should speed up the allocation of resources and population, especially the flow of production factors such as physical capital and labor. Further development of green urbanization and coordinated development of urbanization can drive environmental protection and economic growth. Finally, in terms of trade liberalization, countries should expand industrial development and improve trade structures, such as controlling emissions-oriented imports through reforms aimed at reducing carbon dioxide emissions and liberalizing trade.

This study has certain limitations that can be addressed in future studies, specifically, this study did not consider some important variables, such as technological innovation and renewable energy, which have great potential to reduce carbon emissions. Validation of the environmental Kuznets curve (EKC) was not tested in this study.

Data availability statement

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

Author contributions

YY, XX, JY, and TZ conceptualized and revised the study, software data curation, editing and literature search.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Akerboom, S., and Craig, R. K. (2022). How law structures public participation in environmental decision making: A comparative law approach. *Env. Pol. Gov.* 32, 232–246. doi:10.1002/eet.1986

Aladejare, S. A. (2022). Natural resource rents, globalisation and environmental degradation: New insight from 5 richest african economies. *Resour. Policy* 78, 102909. doi:10.1016/j.resourpol.2022.102909

Anwar, A., Chaudhary, A. R., and Malik, S. (2022). Modeling the macroeconomic determinants of environmental degradation in E-7 countries: The role of technological innovation and institutional quality. *J. Public Aff.*, e2834. doi:10.1002/pa.2834

Apergis, N., Pinar, M., and Unlu, E. (2022). How do foreign direct investment flows affect carbon emissions in BRICS countries? Revisiting the pollution haven hypothesis using bilateral FDI flows from OECD to BRICS countries. *Environ. Sci. Pollut. Res. Int.*, 1–13. doi:10.1007/s11356-022-23185-4

Ashraf, J., Luo, L., and Anser, M. K. (2022). Do BRI policy and institutional quality influence economic growth and environmental quality? An empirical analysis from South asian countries affiliated with the belt and road initiative. *Environ. Sci. Pollut. Res.* 29 (6), 8438–8451. doi:10.1007/s11356-021-16330-y

Ashraf, J., Luo, L., and Khan, M. A. (2022). The spillover effects of institutional quality and economic openness on economic growth for the belt and road initiative (BRI) countries. *Spat. Stat.* 47, 100566. doi:10.1016/j.spasta.2021.100566

Awad, A., and Warsame, M. H. (2022). The poverty-environment nexus in developing countries: Evidence from heterogeneous panel causality methods, robust to cross-sectional dependence. *J. Clean. Prod.* 331, 129839. doi:10.1016/j.jclepro.2021.129839

Azam A, A., Rafiq, M., Shafique, M., and Yuan, J. (2021). Renewable electricity generation and economic growth nexus in developing countries: An ARDL approach. *Econ. Research-Ekonomska Istraživanja* 34 (1), 2423–2446. doi:10.1080/1331677x.2020.1865180

Azam M, M., Liu, L., and Ahmad, N. (2021). Impact of institutional quality on environment and energy consumption: Evidence from developing world. *Environ. Dev. Sustain.* 23 (2), 1646–1667. doi:10.1007/s10668-020-00644-x

Azam, M., and Raza, A. (2022). Does foreign direct investment limit trade-adjusted carbon emissions: Fresh evidence from global data. *Environ. Sci. Pollut. Res.* 29 (25), 37827–37841. doi:10.1007/s11356-021-18088-9

Balsalobre-Lorente, D., Driha, O. M., Halkos, G., and Mishra, S. (2022). Influence of growth and urbanization on CO2 emissions: The moderating effect of foreign direct investment on energy use in BRICS. *Sustain. Dev.* 30 (1), 227–240. doi:10.1002/sd.2240

Banday, U. J., Murugan, S., and Maryam, J. (2021). Foreign direct investment, trade openness and economic growth in BRICS countries: Evidences from panel data. *Transnatl. Corp. Rev.* 13 (2), 211–11. doi:10.1080/19186444.2020.1851162

Bawole, J. N., and Langnel, Z. (2021). Corruption-induced inhibitions to business: What business leaders have to say in Ghana. *J. Afr. Bus.*, 1–18. doi:10.1080/15228916.2021.2018226

Breusch, T. S., and Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *Rev. Econ. Stud.* 47 (1), 239–253. doi:10.2307/2297111

Castellacci, F., Oguguo, P. C., and Freitas, I. M. B. (2022). Quality of pro-market national institutions and firms' decision to invest in R&D: Evidence from developing and transition economies. *Eurasian Bus. Rev.* 12 (1), 35–57. doi:10.1007/s40821-022-00202-7

Chen, J., Hu, X., Razi, U., and Rexhepi, G. (2021). The sustainable potential of efficient air-transportation industry and green innovation in realising environmental sustainability in G7 countries. *Economic Research Ekonomska I Straživanja* 1 (35), 3814–3835. doi:10.1080/1331677X.2021.2004190

Chen, Z., Paudel, K. P., and Zheng, R. (2022). Pollution halo or pollution haven: Assessing the role of foreign direct investment on energy conservation and emission reduction. *J. Environ. Plan. Manag.* 65 (2), 311–336. doi:10.1080/09640568.2021.1882965

Dhaoui, I. (2022). E-government for sustainable development: Evidence from MENA countries. *J. Knowl. Econ.* 13 (3), 2070–2099. doi:10.1007/s13132-021-00791-0

Djellouli, N., Abdelli, L., Elheddad, M., Ahmed, R., and Mahmood, H. (2022). The effects of non-renewable energy, renewable energy, economic growth, and foreign direct investment on the sustainability of African countries. *Renew. Energy* 183, 676–686. doi:10.1016/j.renene.2021.10.066

Dogru, T., Bulut, U., and Sirakaya-Turk, E. (2021). Modeling tourism demand: Theoretical and empirical considerations for future research. *Tour. Econ.* 27 (4), 874–889. doi:10.1177/1354816619894460

Dumitrescu, E. I., and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Econ. Model.* 29 (4), 1450–1460. doi:10.1016/j.econmod.2012.02.014

Eberhardt, M., and Bond, S. (2009). *Cross-section dependence in nonstationary panel models: A novel estimator.*

El Menyari, Y. (2021). Effect of tourism FDI and international tourism to the economic growth in Morocco: Evidence from ARDL bound testing approach. *J. Policy Res. Tour. Leis. Events* 13 (2), 222–242. doi:10.1080/19407963.2020.1771567

Espoir, D. K., Mudiangombe, B. M., Bannor, F., Sunge, R., and Tshitaka, J. L. M. (2022). CO2 emissions and economic growth: Assessing the heterogeneous effects across climate regimes in Africa. *Sci. Total Environ.* 804, 150089. doi:10.1016/j.scitotenv.2021.150089

Ge, M., Kannaiah, D., Li, J., Khan, N., Shabbir, M. S., Bilal, K., et al. (2022). Does foreign private investment affect the clean industrial environment? Nexus among foreign private investment, CO2 emissions, energy consumption, trade openness, and sustainable economic growth. *Environ. Sci. Pollut. Res.* 29, 26182–26189. doi:10.1007/s11356-022-18814-x

Godil, D. I., Sharif, A., Agha, H., and Jermsittiparsert, K. (2020). The dynamic nonlinear influence of ICT, financial development, and institutional quality on CO2 emission in Pakistan: New insights from QARDL approach. *Environ. Sci. Pollut. Res.* 27 (19), 24190–24200. doi:10.1007/s11356-020-08619-1

Gyamfi, B. A., Adebayo, T. S., and Ogbolime, U. (2022). Towards a sustainable consumption approach: The effect of trade flow and clean energy on consumption-based carbon emissions in the sub-saharan african countries. *Environ. Sci. Pollut. Res.* 29, 54122–54135. doi:10.1007/s11356-022-19340-6

Hadj, T. B., and Ghodbane, A. (2022). A moderated mediation model of the effect of foreign direct investments on CO2 emissions: Panel data evidence from GCC countries. *J. Knowl. Econ.* 13 (2), 904–925. doi:10.1007/s13132-021-00765-2

Hao, Y., Guo, Y., Guo, Y., Wu, H., and Ren, S. (2020). Does outward foreign direct investment (OFDI) affect the home country's environmental quality? The case of China. *Struct. Change Econ. Dyn.* 52, 109–119. doi:10.1016/j.strueco.2019.08.012

Hashem, P. M. (2021). General diagnostic tests for cross-sectional dependence in panels. *Empir. Econ.* 60 (1), 13–50. doi:10.1007/s00181-020-01875-7

Hashemizadeh, A., Bui, Q., and Kongbuamai, N. (2021). Unpacking the role of public debt in renewable energy consumption: New insights from the emerging countries. *Energy* 224, 120187. doi:10.1016/j.energy.2021.120187

Hope Sr, K. R. (2020). Peace, justice and inclusive institutions: Overcoming challenges to the implementation of sustainable development goal 16. *Glob. Change, Peace & Secur.* 32 (1), 57–77. doi:10.1080/14781158.2019.1667320

Hu, G. G. (2021). Is knowledge spillover from human capital investment a catalyst for technological innovation? The curious case of fourth industrial revolution in BRICS economies. *Technol. Forecast. Soc. change* 162, 120327. doi:10.1016/j.techfore.2020.120327

İnal, V., Addi, H. M., Çakmak, E. E., Torusdağ, M., and Çalışkan, M. (2022). The nexus between renewable energy, CO2 emissions, and economic growth: Empirical evidence from african oil-producing countries. *Energy Rep.* 8, 1634–1643. doi:10.1016/j.egyr.2021.12.051

Iqbal, A., Tang, X., and Rasool, S. F. (2022). Investigating the nexus between CO2 emissions, renewable energy consumption, FDI, exports and economic growth: Evidence from BRICS countries. *Environ. Dev. Sustain.*, 1–30.

Islam, M., Khan, M. K., Tareque, M., Jehan, N., and Dagar, V. (2021). Impact of globalization, foreign direct investment, and energy consumption on CO2 emissions in Bangladesh: Does institutional quality matter? *Environ. Sci. Pollut. Res.* 28 (35), 48851–48871. doi:10.1007/s11356-021-13441-4

Jahanger, A., Usman, M., and Balsalobre-Lorente, D. (2022). Linking institutional quality to environmental sustainability. *Sustainable Development* 6 (30), 1749–1765. doi:10.1002/sd.2345

Jiang, H. D., Purohit, P., Liang, Q. M., Dong, K., and Liu, L. J. (2022). The cost-benefit comparisons of China's and India's NDCs based on carbon marginal abatement cost curves. *Energy Econ.* 109, 105946. doi:10.1016/j.eneco.2022.105946

Jiang, H. D., Xue, M. M., Dong, K. Y., and Liang, Q. M. (2022). How will natural gas market reforms affect carbon marginal abatement costs? Evidence from China. *Econ. Syst. Res.* 34 (2), 129–150. doi:10.1080/09535314.2020.1868410

Jiang, M., Luo, S., and Zhou, G. (2020). Financial development, OFDI spillovers and upgrading of industrial structure. *Technol. Forecast. Soc. Change* 155, 119974. doi:10.1016/j.techfore.2020.119974

Jiang Q, Q., Rahman, Z. U., Zhang, X., Guo, Z., and Xie, Q. (2022). An assessment of the impact of natural resources, energy, institutional quality, and financial development on CO2 emissions: Evidence from the B&R nations. *Resour. Policy* 76, 102716. doi:10.1016/j.resourpol.2022.102716

Kamah, M., Riti, J. S., and Bin, P. (2021). Inclusive growth and environmental sustainability: The role of institutional quality in sub-saharan Africa. *Environ. Sci. Pollut. Res.* 28 (26), 34885–34901. doi:10.1007/s11356-021-13125-z

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *J. Econ.* 90 (1), 1–44. doi:10.1016/s0304-4076(98)00023-2

Karaduman, C. (2022). The effects of economic globalization and productivity on environmental quality: Evidence from newly industrialized countries. *Environ. Sci. Pollut. Res.* 29 (1), 639–652. doi:10.1007/s11356-021-15717-1

Karim, S., Appiah, M., Naeem, M. A., Lucey, B. M., and Li, M. (2022). Modelling the role of institutional quality on carbon emissions in Sub-Saharan African countries. *Renewable Energy* 198, 213–221. doi:10.1016/j.renene.2022.08.074

Khan, H., Weili, L., and Khan, I. (2022). The role of institutional quality in FDI inflows and carbon emission reduction: Evidence from the global developing and belt road initiative countries. *Environ. Sci. Pollut. Res.* 29 (20), 30594–30621. doi:10.1007/s11356-021-17958-6

Khan, Z., Ali, S., Dong, K., and Li, R. Y. M. (2021). How does fiscal decentralization affect CO2 emissions? The roles of institutions and human capital. *Energy Econ.* 94, 105060. doi:10.1016/j.eneco.2020.105060

Lakshmi, G., Saha, S., and Bhattarai, K. (2021). Does corruption matter for stock markets? The role of heterogeneous institutions. *Econ. Model.* 94, 386–400. doi:10.1016/j.econmod.2020.10.011

Lenzen, M., Malik, A., Li, M., Fry, J., Weisz, H., Pichler, P. P., et al. (2020). The environmental footprint of health care: A global assessment. *Lancet Planet. Health* 4 (7), e271–e279. doi:10.1016/s2542-5196(20)30121-2

Liu, Y., Sadiq, F., Ali, W., and Kumail, T. (2022). Does tourism development, energy consumption, trade openness and economic growth matters for ecological footprint: Testing the Environmental Kuznets Curve and pollution haven hypothesis for Pakistan. *Energy* 245, 123208. doi:10.1016/j.energy.2022.123208

Liu, Y., Wang, A., and Wu, Y. (2021). Environmental regulation and green innovation: Evidence from China's new environmental protection law. *J. Clean. Prod.* 297, 126698. doi:10.1016/j.jclepro.2021.126698

Lucas, R. E. (1988). On the mechanics of economic development. *J. Monetary Econ.* 22 (1), 3–42. doi:10.1016/0304-3932(88)90168-7

Luo, Y., Guo, C., Ali, A., and Zhang, J. (2022). A dynamic analysis of the impact of FDI, on economic growth and carbon emission, evidence from China, India and Singapore. *Environ. Sci. Pollut. Res.* 29, 82256–82270. doi:10.1007/s11356-022-21546-7

Majeed, M. T., Mazhar, M., Samreen, I., and Tauqir, A. (2022). Economic complexities and environmental degradation: Evidence from OECD countries. *Environ. Dev. Sustain.* 24 (4), 5846–5866. doi:10.1007/s10668-021-01687-4

Maza, A. (2022). Regional differences in okun's law and explanatory factors: Some insights from europe. *Int. Regional Sci. Rev.* 45, 555–580. doi:10.1177/01600176221082309

Mohanty, S., and Sethi, N. (2022). The energy consumption-environmental quality nexus in BRICS countries: The role of outward foreign direct investment. *Environ. Sci. Pollut. Res.* 29 (13), 19714–19730. doi:10.1007/s11356-021-17180-4

Murshed, M., Ahmed, R., Kumpamool, C., Bassim, M., and Elheddad, M. (2021). The effects of regional trade integration and renewable energy transition on environmental quality: Evidence from South Asian neighbors. *Bus. Strat. Env.* 30 (8), 4154–4170. doi:10.1002/bse.2862

Murshed, M., Elheddad, M., Ahmed, R., Bassim, M., and Than, E. T. (2022). Foreign direct investments, renewable electricity output, and ecological footprints: Do financial globalization facilitate renewable energy transition and environmental welfare in Bangladesh? *Asia-Pac. Financ. Mark.* 29 (1), 33–78. doi:10.1007/s10690-021-09335-7

Myrdal, G., and Sitohang, P. (1957). *Economic theory and under-developed regions*. Londres: Gunnar myrdal: Geralcl Duckworth & Co.

Nair, M., Arvin, M. B., Pradhan, R. P., and Bahmani, S. (2021). Is higher economic growth possible through better institutional quality and a lower carbon footprint? Evidence from developing countries. *Renew. Energy* 167, 132–145. doi:10.1016/j.renene.2020.11.056

North, D. C. (1990). Institutions, institutional change and economic performance: Institutions. *J. Econ. Behav. Organ.* 18 (1), 142–144. doi:10.1016/0167-2681(92)90062-g

Ntom Udemba, E., Onyenegecha, I., and Olasehinde-Williams, G. (2022). Institutional transformation as an effective tool for reducing corruption and enhancing economic growth: A panel study of west african countries. *J. Public Aff.* 22 (2), e2389.

Obobisa, E. S., Chen, H., and Mensah, I. A. (2022). The impact of green technological innovation and institutional quality on CO2 emissions in African countries. *Technol. Forecast. Soc. Change* 180, 121670. doi:10.1016/j.techfore.2022.121670

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxf. Bull. Econ. Stats.* 61 (S1), 653–670. doi:10.1111/1468-0084.61.s1.14

Pedroni, P. (2004). Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econ. Theory* 20 (3), 597–625. doi:10.1017/s0266466604203073

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *J. Appl. Econ.* 22 (2), 265–312. doi:10.1002/jae.951

Povitkina, M. (2018). The limits of democracy in tackling climate change. *Environ. Polit.* 27 (3), 411–432. doi:10.1080/09644016.2018.1444723

Pradhan, A. K., Sachan, A., Sahu, U. K., and Mohindra, V. (2022). Do foreign direct investment inflows affect environmental degradation in BRICS nations? *Environ. Sci. Pollut. Res.* 29 (1), 690–701. doi:10.1007/s11356-021-15678-5

Rahman, M. M., Nepal, R., and Alam, K. (2021). Impacts of human capital, exports, economic growth and energy consumption on CO2 emissions of a cross-sectionally dependent panel: Evidence from the newly industrialized countries (NICs). *Environ. Sci. Policy* 121, 24–36. doi:10.1016/j.envsci.2021.03.017

Raza, S. A., Shah, N., and Arif, I. (2021). Relationship between FDI and economic growth in the presence of good governance system: Evidence from OECD countries. *Glob. Bus. Rev.* 22 (6), 1471–1489. doi:10.1177/0972150919833484

Rehman, A., Ma, H., Ozturk, I., and Radulescu, M. (2022). Revealing the dynamic effects of fossil fuel energy, nuclear energy, renewable energy, and carbon emissions on Pakistan's economic growth. *Environ. Sci. Pollut. Res.* 29, 48784–48794. doi:10.1007/s11356-022-19317-5

Rodríguez-Caballero, C. V. (2022). Energy consumption and GDP: A panel data analysis with multi-level cross- sectional dependence. *Econ. Statistics* 23, 128–146. doi:10.1016/j.ecosta.2020.11.002

Romer, P. M. (1986). Increasing returns and long-run growth. *J. Political Econ.* 94 (5), 1002–1037. doi:10.1086/261420

Rostow, W. W. (1990). *The stages of economic growth: A non-communist manifesto*. Cambridge University Press.

Salman, M., Long, X., Dauda, L., and Mensah, C. N. (2019). The impact of institutional quality on economic growth and carbon emissions: Evidence from Indonesia, South Korea and Thailand. *J. Clean. Prod.* 241, 118331. doi:10.1016/j.jclepro.2019.118331

Saud, S., Chen, S., and Haseeb, A. (2020). The role of financial development and globalization in the environment: Accounting ecological footprint indicators for selected one-belt-one-road initiative countries. *Journal of Cleaner Production* 250, 119518. doi:10.1016/j.jclepro.2019.119518

Shah, S. A. R., Naqvi, S. A. A., Riaz, S., Anwar, S., and Abbas, N. (2020). Nexus of biomass energy, key determinants of economic development and environment: A fresh evidence from Asia. *Renew. Sustain. Energy Rev.* 133, 110244. doi:10.1016/j.rser.2020.110244

Shahzad, U., Schneider, N., and Jebli, M. B. (2021). How coal and geothermal energies interact with industrial development and carbon emissions? An autoregressive distributed lags approach to the Philippines. *Resour. Policy* 74, 102342. doi:10.1016/j.resourpol.2021.102342

Shleifer, A., and Vishny, R. W. (1993). Corruption. *Q. J. Econ.* 108 (3), 599–617. doi:10.2307/2118402

Simionescu, M., and Schneider, N. (2022). Revisiting the nuclear energy-income nexus in Europe: An application of the JKS panel causality test with cross-sectional dependence and heterogeneity. *Intl. J. Energy Res.* 46 (6), 8328–8351. doi:10.1002/er.7731

Singhania, M., and Saini, N. (2021). Demystifying pollution haven hypothesis: Role of FDI. *J. Bus. Res.* 123, 516–528. doi:10.1016/j.jbusres.2020.10.007

Sinha, M., and Sengupta, P. P. (2022). FDI inflow, ICT expansion and economic growth: An empirical study on Asia-pacific developing countries. *Glob. Bus. Rev.* 23 (3), 804–821. doi:10.1177/0972150919873839

Sokhanvar, A., and Jenkins, G. P. (2021). Impact of foreign direct investment and international tourism on long- run economic growth of Estonia. *J. Econ. Stud.* 49, 364–378. doi:10.1108/jes-11-2020-0543

Solow, R. M. (1956). A contribution to the theory of economic growth. *Q. J. Econ.* 70 (1), 65–94. doi:10.2307/1884513

Sun, H., Edziah, B. K., Sun, C., and Kporsu, A. K. (2022). Institutional quality and its spatial spillover effects on energy efficiency. *Socio-Economic Plan. Sci.* 83, 101023. doi:10.1016/j.seps.2021.101023

Teal, F., and Eberhardt, M. (2010). *Productivity analysis in global manufacturing production*. University of Oxford.

Teng, X., Zhao, Q., Zhang, P., Liu, L., Hu, H., Yue, Q., et al. (2021). Implementing marine functional zoning in China. *Mar. Policy* 132, 103484. doi:10.1016/j.marpol.2019.02.055

Udemba, E. N. (2021). Mitigating environmental degradation with institutional quality and foreign direct investment (FDI): New evidence from asymmetric approach. *Environ. Sci. Pollut. Res.* 28 (32), 43669–43683. doi:10.1007/s11356-021-13805-w

Udemba, E. N., and Philip, L. D. (2022). Policy insight from renewable energy, foreign direct investment (FDI), and urbanization towards climate goal: Insight from Indonesia. *Environ. Sci. Pollut. Res.* 29, 54492–54506. doi:10.1007/s11356-022-19599-9

Udemba, E. N., and Yalçıntaş, S. (2021). Interacting force of foreign direct invest (FDI), natural resource and economic growth in determining environmental performance: A nonlinear autoregressive distributed lag (NARDL) approach. *Resour. Policy* 73, 102168. doi:10.1016/j.resourpol.2021.102168

Ullah, A., Zhao, X., Abdul Kamal, M., and Zheng, J. (2022). Environmental regulations and inward FDI in China: Fresh evidence from the asymmetric autoregressive distributed lag approach. *Int. J. Fin. Econ.* 27 (1), 1340–1356. doi:10.1002/ijfe.2218

Ulucak, R. (2020). The pathway toward pollution mitigation: Does institutional quality make a difference? *Bus. Strat. Env.* 29 (8), 3571–3583. doi:10.1002/bse.2597

Uzair Ali, M., Gong, Z., Ali, M. U., Asmi, F., and Muhammad, R. (2022). CO_2 emission, economic development, fossil fuel consumption and population density in India, Pakistan and Bangladesh: A panel investigation. *Int. J. Fin. Econ.* 27 (1), 18–31. doi:10.1002/ijfe.2134

Vanderhorst, H. R., Suresh, S., Renukappa, S., and Heesom, D. (2021). Strategic framework of Unmanned Aerial Systems integration in the disaster management public organisations of the Dominican Republic. *Int. J. Disaster Risk Reduct.* 56, 102088. doi:10.1016/j.ijdrr.2021.102088

Wang, M. L., Ntim, V. S., Yang, J., Zheng, Q., and Geng, L. (2022). Effect of institutional quality and foreign direct investment on economic growth and environmental quality: Evidence from african countries. *Econ. Research-Ekonomska Istraživanja* 35 (1), 4065–4091. doi:10.1080/1331677x.2021.2010112

Wei, X., Mohsin, M., and Zhang, Q. (2022). Role of foreign direct investment and economic growth in renewable energy development. *Renew. Energy* 192, 828–837. doi:10.1016/j.renene.2022.04.062

Westerlund, J. (2007). Testing for error correction in panel data. *Oxf. Bull. Econ. Stats.* 69, 709–748. doi:10.1111/j.1468-0084.2007.00477.x

Xu, L., Wang, X., Wang, L., and Zhang, D. (2022). Does technological advancement impede ecological footprint level? The role of natural resources prices volatility, foreign direct investment and renewable energy in China. *Resour. Policy* 76, 102559. doi:10.1016/j.resourpol.2022.102559

Yang, B., Ali, M., Hashmi, S. H., and Jahanger, A. (2022). Do income inequality and institutional quality affect CO2 emissions in developing economies? *Environ. Sci. Pollut. Res.* 29 (28), 42720–42741. doi:10.1007/s11356-021-18278-5

Yang, X., Li, N., Mu, H., Pang, J., Zhao, H., and Ahmad, M. (2021). Study on the long-term impact of economic globalization and population aging on CO2 emissions in OECD countries. *Sci. Total Environ.* 787, 147625. doi:10.1016/j.scitotenv.2021.147625

You, W., Zhang, Y., and Lee, C. C. (2022). The dynamic impact of economic growth and economic complexity on CO2 emissions: An advanced panel data estimation. *Econ. Analysis Policy* 73, 112–128. doi:10.1016/j.eap.2021.11.004

Zafar, M. W., Qin, Q., and Zaidi, S. A. H. (2020). Foreign direct investment and education as determinants of environmental quality: The importance of post Paris Agreement (COP21). *J. Environ. Manag.* 270, 110827. doi:10.1016/j.jenvman.2020.110827

Zafar, M. W., Shahbaz, M., Sinha, A., Sengupta, T., and Qin, Q. (2020). How renewable energy consumption contribute to environmental quality? The role of education in OECD countries. *J. Clean. Prod.* 268, 122149. doi:10.1016/j.jclepro.2020.122149

Zakari, A., and Khan, I. (2022). Boosting economic growth through energy in Africa: The role of Chinese investment and institutional quality. *J. Chin. Econ. Bus. Stud.* 20 (1), 1–21. doi:10.1080/14765284.2021.1968709

Zakaria, M., and Bibi, S. (2019). Financial development and environment in South Asia: The role of institutional quality. *Environ. Sci. Pollut. Res.* 26 (8), 7926–7937. doi:10.1007/s11356-019-04284-1