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Environmental sustainability with the role of green innovation and economic growth in India with bootstrap ARDL approach

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This paper applies a novel Bootstrap Autoregressive Distributed Lag (BARDL) approach to investigate the relationship between green innovation (GI), economic growth (GDP), drama and film (D&F) industry, and environmental sustainability in India for the 1995 to 2020 period. The data has been checked for its stationarity by applying the Zivot and Andrews (ZA) unit root test, and the cointegration test results suggest a long-run equilibrium relationship between the variables. The empirical finding of long-run estimates reveals that 1% augments of GI, GDP, and D&F industry increase CO_2 emissions by −0.079, 0.566%, and 0.143%, respectively. Furthermore, the main results indicate that GDP and the D&F industry have statistically significant positive effects on CO_2 emissions, and GI has statistically significant negative effects on CO_2 emissions. The GI leads to lower environmental damage by reducing carbon emissions. Regarding causal relationships, bidirectional causality is found between D&F and CO_2 emissions, GI and CO_2 emissions. In addition, a unidirectional causality is also revealed from GDP to CO_2 emissions. Based on the finding of this study, policy implications are suggested for India.

KEYWORDS
green innovation, economic growth, environmental sustainability, BARDL, India

Introduction

Developing countries are facing the issue of environmental deterioration. Environmental deterioration is harmed by using energy consumption for economic growth, but the consequences of environmental deterioration cannot be ignored. Indian economy is growing rapidly same trend in the future. India's economy depends on industrial production, agriculture, foreign investment, and film industries, and agriculture is the important dominant sector of the nation, but due to repaid growth of the industrial sector in India, the agricultural land is cutting. Besides this, the rapid increase in population causes degradation; India is the top ranked country in Asian nations that faces the issue of deforestation. An increase in financial development and the industrial sector's use of energy for growth causes ecological deterioration. India is facing high energy demand for which traditional energy sources are used to meet its fast-rising demand for energy. (Khan M. K. et al., 2019, Khan F et al., 2019) started that traditional energy sources emit CO_2 emissions, contributing to the deterioration of ecological quality. (Malik, 2021) stated that environmental deterioration affects the environment and health of human beings in India. (Shahbaz et al., 2013a, Shahbaz et al., 2013b) Stated that fossil fuels use for daily life, the expulsion of massive smoke from factories and the consumption of wood as an energy resource to boost carbon dioxide. CO_2 emissions have a devastating effect on the economy and other sectors such as agriculture and forestry.

Due to policies that increase income, developing countries are expanding their economies and urbanizing their populations, which could endanger the environment. Energy use and CO_2 emissions could rise due to growing urbanization in developing nations (He et al., 2017). The boosted energy demand in South Asian nations and their massive dependence on fossil fuels has created an alarming situation for ecological qualities, GHG emissions and pollution (James et al., 2013). Moreover, Countries have used various energy policies due to the aforementioned international agreements to reduce CO2 emissions. Governments impose penalties for excessive consumption or credits and subsidies for modernization and the use of clean energy to encourage adherence to the policies. Aiming for a net-zero energy footprint and raising public awareness of new technologies, these policies can succeed if they are set at an appropriate level. However, developing nations are also a source of growing concern, and it is crucial to develop environmental policies that support economic growth and are consistent with the goals set. Finding long-term causal effects on particular policies is essential and relevant when implementing these new global programs.

The potential benefits of technology innovation have contributed significantly to its dramatic growth in recent years (Najmi et al., 2020; Shu et al., 2022). For instance, technological innovation aids in reducing environmental pollution and improving resource use quality. It also increases green technologies' cost-effectiveness (Ielasi et al., 2018; Manigandan et al., 2021). The adoption of clean and green technologies is likely to be hampered by certain hindrances, both locally and globally, although there is agreement among the nations regarding their progress towards sustainable growth (Biresselioglu et al., 2018; Su et al., 2021). Regularly, eco-friendly technology is considered relatively desirable, particularly for emerging nations. Nevertheless, such technologies have the potential to extend into the future as well (Yu et al., 2022). Furthermore, a company is more likely to invest in such technologies, particularly if they decrease misappropriation and ineffectiveness by enhancing the productivity of the company (Guo et al., 2022).

There are two ways in which the media, specifically the drama and film industries (D&F), can contribute to the drive for pollution reduction, environmental preservation, and, most importantly, global warming mitigation. The public can first convey the importance of environmental protection by creating and developing relevant content and producing investigative reports, short films, and awareness campaigns (Chen and Valdmanis, 2019). The second aspect could be the industry's role as a consumer of energy and resources, with each scene having a different demand and each idea having a different production setup. As a result, this industry will likely contribute to the rise in pollution and environmental degradation (Brereton, 2014). It is noted that because of being non-ecologically friendly, this industry has always been criticized for its neglect (Lopera-Mármol and Jiménez-Morales, 2021). Furthermore, despite their ability to draw and shape the societal narrative, the television sector in general, and drama and film, have been reported as the main contributors to CO_2 emissions, operations of socially unequal, pollutions-releasing, and endeavors (Brereton, 2014; Forster et al., 2020). Based on the findings of the 2019 report, the industry involved in the audio and video sector is said to generate over two million tons of carbon per year (Salami et al., 2019).

India is one of the most populous countries whose economy primarily relies on manufacturing enterprises which are the major causes of pollution spreading into the air, adversely affecting the natural resources and health of living beings. The manufacturing organizations taking care of the environmental and social concerns of the general public have sustainable business development. On the other hand, the countries which are only interested in profits and do not care for environmental quality and social well-being have a backward position in the market. There are multiple contributions that the current study attempts to make. Firstly, the present study explores the effects of the drama and film industry (D&F) and economic growth (GDP) and green innovations together on the environmental performance (EP) in India, which possess the potential both in terms of D&F and GDP but also emits pollution significantly. Secondly, to the best of the author's knowledge, this is the first study to analyze the green innovations, economic growth, and drama and film industry indices as the independent variable in this country. Thirdly, the current study is statistically sound, based on the employment of the unique and recent technique suggested by McNown et al. (2018) named "Bootstrap Autoregressive Distributed Lag" which is far robust and rigorous in terms of predictability, especially when the dataset possesses weak statistical power or low sample size.

The structure of this article is as follows: the second section is a literature review. The third section provides data and methods. Empirical results and discussion have been discussed in the fourth section. Finally, the last section provides the conclusion and policy recommendation.

Literature review

Green tech innovation effect on CO_2 emissions

Growing international concern about green development has changed several countries from simply working to achieve growth to developing a sustainable economic model to protect environmental health (Lorek and Spangenberg, 2014). Without the former, true green evolution would not be possible (Yue et al., 2021). Technology and scientific innovations are important to green growth (Song et al., 2019), and researchers have confirmed this assertion in several parts of the world (e.g., (Padilla-Pérez and Gaudin, 2014) in the central US (Grover, 2013), in India).

In recent years, green technology innovations have become a global tool for reducing CO2 emissions (Weina et al., 2016; Zhang et al., 2016; Nikzad and Sedigh, 2017; Murshed and Alam, 2021). With rising anxiety over climate change, energy technology innovation was the focus of several researchers. Even though many studies unpack the story of complex networks among the previous and energy consumption, the effect the technological innovation exerts on carbon footprint has not yet been extensively debated. Applying the spatial economic model (Ahmad et al., 2018, Shao et al., 2021), technological innovations based on renewable materials have reduced carbon emissions in China, while traditional energy technology restructuring has failed to reduce environmental damage. Furthermore, the author observed that technological innovation's impacts on toxic emissions were transregional. That means that changes in the geographical region that enjoys energies from renewables will enable carbon mitigation in the surrounding regions (Mohsin et al., 2021).

Moreover, some previous studies argued that the impacts of green innovation on CO_2 emissions vary due to different factors, income, time, and other things (Jaffe et al., 2002). According to several reports (Goh et al., 2017; Wang et al., 2019; Adedoyin et al., 2020), the former efficiently addresses the trade exchanges among economic development and environmental protection because it improves energy efficiency, which is necessary for carbon reduction efforts. Thus, not all agree with this assertion. For instance, (Salman et al., 2019) found no substantial role of energy technology patents in reducing ambient carbon emission in Thailand; green energy technology patents drive down air pollution only in Eastern Thailand. Similarly, (Wang et al., 2021) revealed that technological innovations improve ecological performance in China but have no crucial effect on diluting CO_2 emissions.

Regarding the effect of green innovation on environmental damage, scientists have different views. Some researchers believe that green innovation can decrease CO_2 emissions by using alternative clean energy, carbon capture and storage technologies, and improvements in energy efficiency. For example, Chine's datasets from thirty provinces from 2005–2010 (Feng and Yuan, 1984) proposed that green innovation and research and development (R&D) investment have significant technical spillover effects, which can significantly encourage reducing carbon emissions. Also, scrutinizing the panel dataset of OECD member nations from 2001 to 2015 (Ganda, 2019) suggested that patent output can significantly impact CO_2 emissions. Although innovations and technological investment have different effects on carbon emissions in various nations, there is still evidence suggesting that technological innovation capacity improvements can effectively contribute to CO_2 emission reduction. (Meirun et al., 2021) the BARDL approach explores the dynamics of green innovations in carbon dioxide emissions in the Singapore economy. In an economy like Singapore, there is also intense population density growth, so there is a need to explore the trend of green innovation and CO_2 emissions. The study results from 1991–2017 by BARDL indicate the negative effect of technological innovations on carbon emission (Wu et al., 2020). Explore the role of energy technology and innovations in reducing CO_2 emissions from a spatial perspective. Numerous findings have examined the relationship between energy tech innovations and energy consumption, while they also point out that the association between green discovery and CO_2 emissions has not received enough attention. The research results show that green tech innovations' play a significant role in reducing carbon emissions.

Drama and film industry effect on CO_2 emissions

The drama and film industry is one of the strategic locomotive industrial sectors of the economy, which contributes significantly to society's moral development and economy (İncekara et al., 2013). Film production involves various steps, from film concept and production to marketing and distribution. Moreover, this industry needs high energy resources and enough time to run its operations (Meilani, 2021). Climate change is a major issue and is highly dependent on fossil fuel consumption, mainly from greenhouse gases accelerating global warming caused by industry (Collins et al., 2013). During the production process of films and plays, substantial amounts of waste are generated, and the high use of energy resources causes air and noise pollution. The drama industry's ecological footprint consists of raw material in sets, plastic bottles, photocopies, lighting equipment, other waste materials and gasoline.

Furthermore, with the enormous investments made in France, Europe, and the United States, the drama and film industry generates large amounts of greenhouse gas emissions

(Corbett, 2006). Moreover, the British Academy of Television and Film Art aims to decrease CO_2 emissions through sustainable film production by 2050. The existing literature provides few studies to assess the drama and film industry's effect on environmental sustainability. (Ahmed et al., 2020, Sun et al., 2022, Victory, 2014). Conducted qualitative studies to emphasize the significance of environmentally friendly practices for the film industry to lessen its environmental impact. The studies have emphasized the role of the production manager as an environmental manager responsible for taking several sustainable initiatives during production and implementing environmentally-friendly policies.

(Malmodin and Lundén, 2018) explained the carbon footprints of the media and entertainment industry with previously predicted footprint size. By adopting the use of energy and life cycle greenhouse gas emissions dataset, the report found that the carbon footprints of the media and entertainment industry decreased in size with time due to the adoption of advanced information technology worldwide. (Tsaurai, 2019, Murshed et al., 2022, Najmi et al., 2021) investigated communication and information technology as supporting variables for the entertainment and media industry. The report found that the development of communication and information technology is helping the entertainment and media industry to reduce barriers to achieving a sustainable environment in developing nations.

A recent study by (Hu et al., 2021) has discussed the importance of the drama and film industry's contribution to Chinese financial development and the impact of the COVID-19 pandemic on the industry. During the slow economic activities in COVID-19, the drama and film stock returns also faced a significant drop in the long run, and low investment was observed. In contrast, digital technology has increased drama, film stock returns, and viewership in the short run. However, in the face of financial uncertainty, China's drama and film industry have a less ecological effect from an environmental perspective. Moreover, (Meilani, 2021) examined the role of carbon footprint in the drama and film industry and found that the drama and film industry plays a major role in corban emissions. However, by gathering data from different sustainable' production reports and literature, the study also examined whether environmentally friendly movements in move production, like the movement of the green output, play an important role in decreasing CO_2 emissions.

Economic growth effect on CO_2 emissions

Since (Kraft & Kraft, 1978) examined the relationship between economic growth and CO_2 emissions for the first time, this topic has gradually caught the attention of many scholars (Wu, 2012; Herrerias et al., 2013; Dong et al., 2016; Zhou et al., 2017; Román-Collado et al., 2018). (Du and Lin, 2015) studied changes in the degree of dependence of Chinese economic growth on fossil fuels from 1985 to 2005 and discovered that during this period, Chinese economic growth has always remained strongly dependent on fossil fuels. Since fossil-fuels is Chines major energy resource, it is of immense practical importance to investigate China's GDP growth dependence on coal-related CO2 emissions.

In the past few years, (Pao & Tsai, 2010) investigated the link between economic growth, energy use and environmental sustainability. Most scholars have been done for developed countries such as the candidate nations and European members (Kasman and Duman, 2015). Early scholars on the same subject have generally concluded that energy use and economic growth cause carbon emissions. (Jiang et al., 2019; Alam et al., 2022) Employ panel Granger causality test to examine the linkage between economic development and carbon dioxide emissions to investigate the effects of institutional factors as a significant contributor to rising carbon emissions by employing the U.S. sectoral-level data. Their research found a Granger causality relationship between the US economy and CO_2 emissions growth.

Scholars on the effects of urbanization and economic growth on CO2 emissions have been conducted over several years. A firstly notable study detected imbalances between rural and urban CO_2 emissions in the 1985s (Heil and Wodon, 1997). After that, a scholar on the relationship between economic development and carbon emission gradually increased (Stocchero et al., 2017). A more current study applying the ARDL model and cointegration approaches attempt to explain the relationship between economic growth and carbon emission. These findings help an EKC (inverted U-shaped curve) linkage between economic growth and CO_2 emissions for eastern and central European countries (Atici, 2009), Romania (Shahbaz et al., 2013a), Malaysia (Saboori and Sulaiman, 2013), Pakistan (Nasir and Ur Rehman, 2011); and India (Tiwari, et, al., 2013; Pachiyappan et, al., 2021); when economic growth and social reaches a certain stage, CO_2 emissions gradually decrease (Sheldon, 2017; Alam, 2022) indicating that there is a decoupling among economic growth and CO_2. emissions. However, some studies do not support an EKC association for Turkey (Ozturk and Acaravci, 2010), and the key factors affecting the decoupling association between economic growth and CO_2 emissions are economic scale, energy use intensity, industrial structure, CO_2 emissions intensity, and land economic output (Alam et al., 2016; Ganda, 2019). Granger causality indicates that economic performance and carbon emissions have a bidirectional causality connection (Chandia et al., 2018). The summary of the literature review is listed in Table 1. Based on this literature review, we conclude that most studies use ARDL and nonlinear ARDL models; for example, Pachiyappan et al. (2021) apply a nonlinear ARDL model to show the nonlinear relationships between environmental pollution, carbon emissions, and health expenditure in India. The results show that positive carbon

TABLE 1 Summary of the literature review.

References	Countries	Data and methodology	Results
Rahman, (2020)	India	1971–2011 Autoregressive distributed lag, Granger causality	Negative association between CO2 emissions and economic growth is shown
Shahbaz et al. (2020)	China	1984–2018 Bootstrapping ARDL	Technological innovations have a negative influence on CO2 emissions
Neog and Kumar Yadava, (2020)	India	1980–2014 Nonlinear ARDL	The positive influence of remittance on CO2 emissions
Kumail S et al. (2020), Kumail T. et al., 2020	Pakistan	1990–2017 ARDL, Bayer and Hanck cointegration	Technological innovations have a negative influence on CO2 emissions
Sinha and Shahbaz (2018)	India	1971–2015 ARDL	Renewable energy reduces CO2 emissions; supported EKC hypothesis
Pata, (2018)	Turkey	1974–2014 ARDL, FMOLS	Insignificant link of renewable energy consumption on CO2 emissions is revealed; supported EKC hypothesis
Alshehry and Belloumi, (2017)	Saudi Arabia	1971–2011 ARDL, Granger causality	EKC hypothesis is not supported
Hashmi et al. (2022)	Global evidence	1970–2015 BARDL	geographical risk have a positive impact on CO2 emissions; supported EKC hypothesis
Lean and Smyth, (2010)	Five Asian countries	1980–2006 Panel VECM, Granger causality test	A nonlinear relationship exists between income and CO2 emissions and a positive relationship between electricity consumption and CO2 emissions
Su et al. (2021)	United States	1971–2000 ARDL, DOLS	Technological innovations have a negative influence on CO2 emissions

TABLE 2 Synopsis of Data description and variable source.

Variables	Acronym	Description	Measures	Data source
Sustainable Environment	CO_2	Ecological footprint per capita	Index	WDI
Green Innovations	GI	Green patent	Number of a patent registered (World intellectual property organization)	OECD
Economic growth	GDP	GDP per capita	current US$	WDI
Drama and film industries	D&F	Stocks of drama and film production companies	Prices index	DataStream database

Data Stream database: https://www.refinitiv.com/en/financial-data/pricing-and-market-data
WDI: https://data.worldbank.org/country/india?view=chart
OECD: https://data.oecd.org/innovation-and-technology.htm

emissions and environmental degradation impact health spending in the long and short runs, while negative environmental pollution and carbon emissions decrease expenditure on health. (Neog and Kumar Yadava, 2020) evidence of a nonlinear cointegrating association between carbon emissions and remittances in both the long and short runs. In this study, we use three BARDL models to study the relationship among the sample variables.

Data and methodology

Data description

To evaluate the role of the film and drama stock prices, and green innovation toward environmental sustainability in China, this study uses the consumption-based CO_2 emissions as the proxy of the sustainable environment (endogenous variable). At the same time, exogenous variables of India's drama and film industry share price are explained through Drama and Film index. However, the other exogenous variable green innovation, represents the number of green patents registered in a year. Lastly, GDP is reflected through real gross product measured in USD. The data for CO_2 and GDP is extracted from WDI, whereas the observations for all variables are gathered from 1995 to 2020. The data sources and variables details are shown in Table 2, and the data is graphically presented in Figure 1.

Model specification

This study examines the impact of green innovations, economic growth (GDP), and the drama and film industry (D&F) on a sustainable environment in India. Green

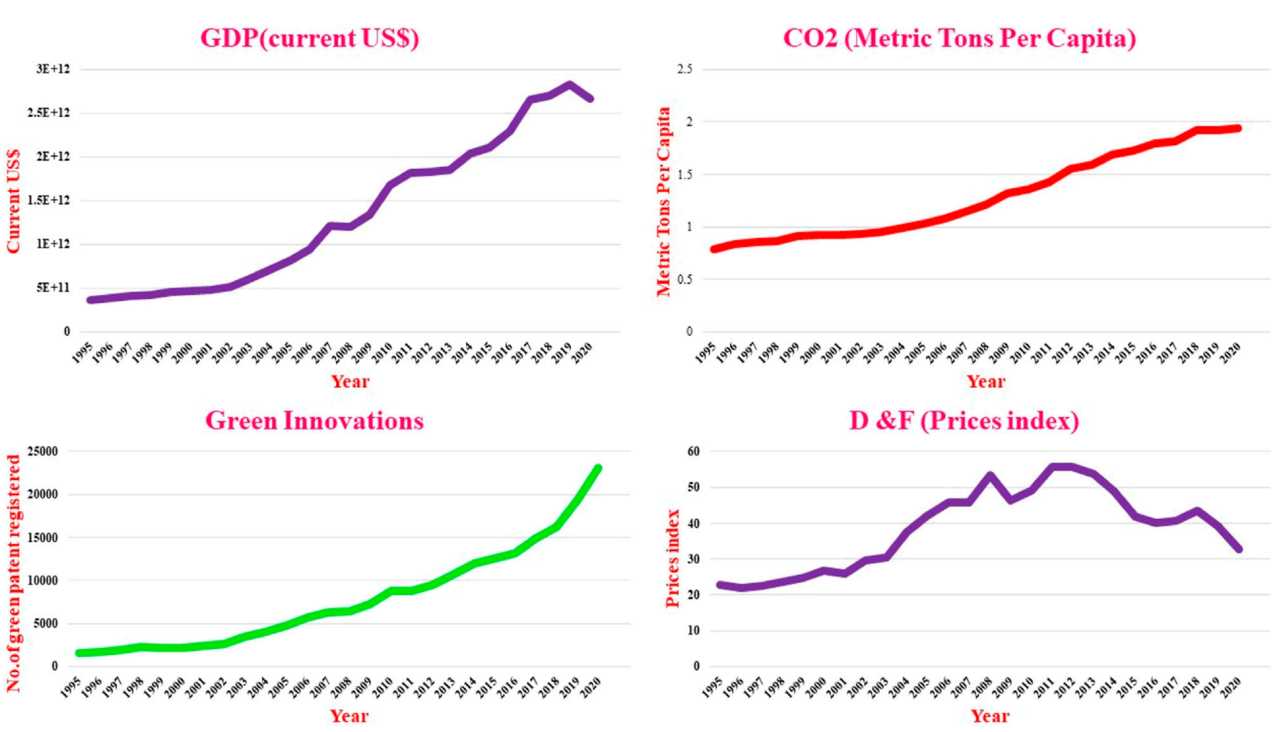

FIGURE 1
Plots of study variables.

innovation, drama, and film prices play a vital role in sustaining the attainable climate by reducing CO_2 emissions. For the study calculation of the sustainable environment, the following log-linear econometric model was used, as recommended by (Ozturk & Acaravci, 2013).

$$InCO_{2t} = \beta_0 + \beta_1 InGI_t + \beta_2 InGDP_t + \beta_3 InDF_t + e_t \quad (1)$$

In Eq. 1, CO_2, GI, GDP, and DF stands for carbon dioxide emissions, green innovations, economic growth, and drama and film prices; e is the residual error term support to independently and identically distributed (i.i.d), respectively. Figure 2 illustrates a comprehensive explanation of the econometric strategy of the present study.

The long-run relationship between green innovations, economic growth, drama and film, and CO_2 emissions are then investigated by applying the bootstrap autoregressive distributed lag (BARDL) for cointegration proposed by (McNown et al., 2018) developing on the ARDL bounds-testing framework of (McNown et al., 2018) determined that these tests have the appropriate size and sensible power properties. To verify the existence of a cointegration nexus, they propose an additional test on the lagged explanatory variables as a complement to the existing F- test and *t*-test (Pesaran et al., 2001). It is necessary to apply these three tests to distinguish between the cases of cointegration and non-cointegration degenerate cases (Goh et al., 2017).

To address this problem, the bootstrap ARDL approach involves a significance test on the coefficients of the lagged explanatory variables. (McNown et al., 2018) performed Monte Carlo Simulations (MCS) and indicated this new test has reasonable size and power properties that are superior to the asymptotic test in the ARDL bound test.

The ARDL model is a dynamic single equation error correction specification. In general, a four-variables ARDL (q, p, r, s) can be written as:

$$\Delta InCO_{2t} = c_0 + \sum_{i=1}^{q}\beta_i \Delta InCO_{2t-i} + \sum_{j=0}^{p}\beta_j \Delta InGI_{t-j} + \sum_{k=0}^{r}\beta_k \Delta InGDP_{t-k} + \sum_{l=0}^{s}\beta_l \Delta InDF_{t-l} + \sum_{u=1}^{t}\chi_u D_{t,u} + w_t \quad (2)$$

Where i, j, k, l, and u are indices of lags: $i = 1, 2, ..., q$, $j = 1, 2, ..., p$, $k = 1, 2, ..., r$, $l = 1, 2, ..., s$, t denotes the periods$t = 1...T$, c_0 is a constant term, CO_2 is the dependent variable, GI, GDP, and FDI denote the explanatory variables, β_i are coefficients on the lags of the endogenous variable, β_j, β_k, β_l, β_m and β_n are coefficients on the lags of the exogenous variables, $D_{t,u}$ is a dummy variable, χ_u are the coefficient of the uth dummy

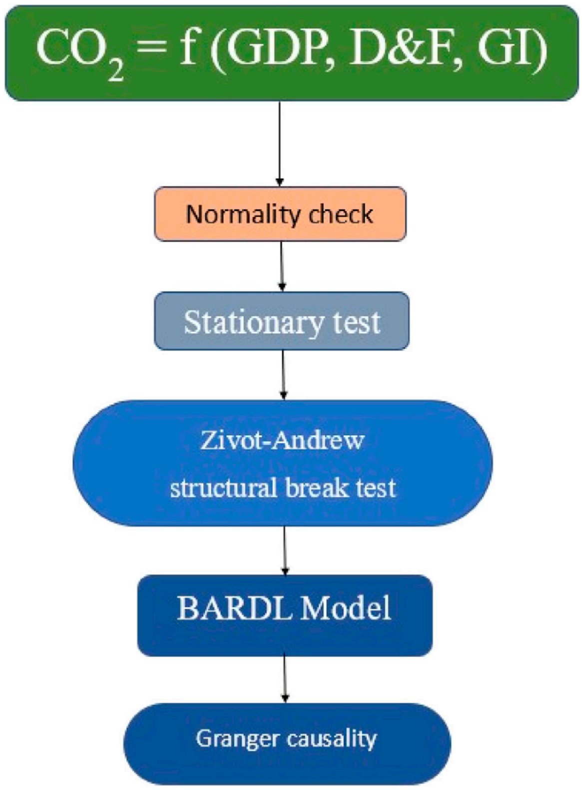

FIGURE 2
The framework of econometric strategy.

variables andw_t is the i. i.d residual error term with mean zero and finite variance σ^2. The constant is ignored for brevity.

Eq. 2 can be re-parameterized and expressed in an error correction model representation as:

$$\Delta InCO_{2t} = c_0 + \sum_{i=1}^{q-1}\eta_i \Delta InCO_{2t-i} + \sum_{j=1}^{p-1}\alpha_j \Delta InGI_{t-j} + \sum_{k=1}^{r-1}\beta_k \Delta InGDP_{t-k} + \sum_{l=1}^{s-1}\delta_l \Delta InDF_{t-l} \sum_{u=1}^{t} v_u D_{t,u} + \phi_1 InCO_{2t-1} + \phi_2 InGI_{t-1} + \phi_3 InGDP_{t-1} + \phi_4 InDF_{t-1} + w_t \quad (3)$$

Where $\phi_1 = 1 - \sum_{i=1}^{q}\beta_i$; $\phi_2 = 1 - \sum_{j=0}^{p}\beta_j$; $\phi_3 = 1 - \sum_{k=0}^{r}\beta_k$; $\phi_4 = 1 - \sum_{l=0}^{s}\beta_l$; and η_i, α_j, β_k, δ_l, χ_m, andγ_n are functions of the original parameters in Eq. 3. The derivation of Eq. 3 from Eq. 2 is the standard re-normalization that is employed in transforming a vector auto-regression in levels in its error-correction from Eq. 3 will be estimated by the ordinary least square (OLS) method. According to (McNown, Yan Sam, et al., 2018), cointegration between CO_2 and GI, GDP, and DF, involves rejection of all three of the following null-hypothesis:

i) F-test based on all relevant terms of error correction (indicated as F_1):

H_0: $\phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$;
against $H_1 \neq \phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq 0$.

ii) F-test based on all of the explanatory variable's terms (indicated as F_2):

H_0: $\phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$;against
H_1: $\phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq 0$.

iii) t-test based on the lagged dependent variable (indicated as T):

$H_0 = \phi_1 = 0$; against $H_1 \neq \phi_1 \neq 0$.

One point to note here is that the traditional ARDL approach generates only the critical values of the bounds test for F_1 and T-tests. However, F_2-test statistics for the lagged explanatory variables are ignored. Using the bootstrap approach, ARDL suggested by (McNown et al., 2018) can provide critical values for all three tests. At the same time, in our effort to deliver empirically robust outcomes, we used the critical values tabulated by (McNown et al., 2018) in this research.

Empirical results and their discussion

The descriptive statistics of the variables of the present study are indicated in Table 3. Based on the outcomes, CO_2 emissions varied between 0.923 and 1.922, with an average value of 1.471 and a standard deviation of 0.321. Similarly, the green innovation (GI) minimum and maximum values are 0.832 and 1.631, respectively, whereas the variable's average value is 1.082 with a standard deviation of 0.249. The mean value of D&F is 2.041, with minimum and maximum ranges of 1.074 and 3.021, with a standard deviation of 0.273. Moreover, the GDP has the highest mean value of 4.331, which varies between 2.451 and 6.412, with a standard deviation of 0.681. Additionally, the Jarque-Bera test rejects the null hypotheses of normal distribution for each variable under consideration at a 5% level of significance.

Table 4 presents the outcomes of the Zivot and Andrews (2002) unit root tests. The ZA unit root test with structural break indicates that all variables are non-stationarity in levels, but they become stationary by differencing them. This implies that all the variables are integrated of 1st-order or I (1). To circumvent the low predicting power of this unit root in the presence of structural breaks, the ZA non-stationary test is applied. The outcomes of this test, as demonstrated in Table 4, indicates that the variables are non-stationary in their levels. They become stationary after 1st-difference. Once the unit root test properties are detected, we move to the cointegration analysis.

After the estimation of unit root, in the next stage, the cointegration of the data in this study was estimated by bootstrap ARDL which many researchers suggest as an

TABLE 3 Descriptive Statistics results.

Variables	Mean	Max	Min	Std. Dev	Skewness	Kurtosis	Jarque -bera
$InCO_2$	1.471	1.922	0.923	0.321	0.671	2.218	3.643
InGI	1.082	1.631	0.832	0.249	0.814	2.267	11.093
InD&F	2.041	3.021	1.074	0.273	0.358	1.576	26.391
InGDP	4.331	6.412	1.451	0.681	0.401	2.787	16.651

Author's Computation.

TABLE 4 Zivot and Andrews unit root test results.

Variable	Trend	Intercept	Both	Variable	Trend	Intercept	Both	Decision
$InCO_2$	−4.261 (2009)	−3.864 (2009)	−3.879 (2009)	$\Delta InCO_2$	−6.071[a] (2013)	−6.871[a] (2013)	7.433[a] (2013)	I (1)
InGI	−3.631							
(2007)	−3.471 (2008)	−3.391 (2007)	ΔInGI	−8.652 (2004)	−7.031[a] (2006)	−8.643[a] (2013)	I (1)	
InDFI	3.871 (2011)	−3.672 (2011)	−4.521 (2010)	ΔInDFI	−9.561[a] (2008)	−9.643[a] (2008)	−9.841[a] (2008)	I (1)
InGDP	−3.421 (2015)	−4.651 (2014)	−4.890 (2014)	ΔInGDP	−5.320[b] (2012)	−5.683[b] (2012)	−5.012[b] (2012)	I (1)

Lg length criterion = Akaike Information Criterion, Δ represents the 1st difference, I(0) and I(1) refer to stationarity at the level and 1st difference, respectively.
[a]Represent the level of significance at 1% and 5%.
[b]Represent the level of significance at 1% and 5%.

TABLE 5 Outcomes of Bootstrap ARDL cointegration approach.

BARDL-cointegration approach						Diagnostic tests			
Estimated models	Lag specification	Break year	F_{PSS}	T_{DV}	F_{IV}	R^2	Q-Stat	LM-(2)	JB
Model-1	(1,1,2,1)	2016	13.832[a]	-4.813[a]	-6.030[a]	0.780	5.301	1.036	0.762

Model 1: $InCO_2 = f$ (InGI + InGDP + InDFI);a denote the 1% level of significance, respectively.

alternative to evaluate more robustly when compared with the other traditional ARDL methods (Sinha and Shahbaz, 2018). As already discussed in greater detail in the methodology, in bootstrap ARDL, the result is the generation and consequently estimated by three test statistics that evaluate three various aspects of the model, which are the whole model estimated by T-statistics, lagged values of the response variables estimated by F_1-statistics, and traditional aspect which is the assessment of lagged values of the explanatory variables estimated by F_2-statistics, which justify the selection of bootstrap ARDL over other related traditional ARDL methods. However, choosing a suitable lag specification is compulsory for bound testing while determining the accurate cointegration in the data; Failure to do so may affect of adversely the validity of the outcomes. Therefore, Bayesian information criteria (BIC) were selected for enhanced power properties appropriate for ascertaining lag specification (McNown et al., 2018). Firstly, the bootstrap ARDL cointegration results are presented in the 2nd column of Table 5. Since all three test statistics (T_{DV}, T_{IV}, and F_{PSS}) are found to be statistically significant at the 1% level, we can claim that there is cointegration between the variables in the model. Moreover, populace equivalency is ensured by an investigation test, Q-statistics; this test confirms the presence of normality and conformation of the outcome's generation of the output through the Jarque-Bera test. In addition, the tests also confirm the absence of multicollinearity, which tends to generate distorted outcomes (Pesaran et al., 2001) and hence is not the focus of concern in this study. The outcomes of the statistics are summarized and presented in Table 5.

After complying with all parameters for robustness as mentioned above, the bootstrap ARDL was used to evaluate the cointegration of short- and long-run keeping carbon emissions as response variables and GI, GDP, and D&F as independent variables. The outcomes of the BARDL approach for these coefficients are reported in Table 6. Precisely, while focusing the level of cointegration among green innovation (GI) on CO_2 emissions, the green innovation (GI) was reported to be negative and significant at a 5% level in the long-run ($\beta = -0.079$, $p < 0.05$) and negative and 1% level of significance in the short-run ($\beta = -0.031$, $p < 0.01$). This means that a 1% increase in GI

TABLE 6 BARDL long and short-run estimates and diagnostic test.

Variable	Coefficient	T-statistics	Coefficient	T-statistics
Long-run			short-run	
Constant	0.451***	3.141	0.149***	−4.216
GI	−0.079**	−2.321	−0.031***	0.567
D&F	0.143***	4.653	0.067**	0.241
GDP	0.566***	-3.813	0.231***	1.431
D_{2009}	0.121***	3.452	0.352***	−4.630
R-square	0.780			
Adj-R-square	0.761			
Durbin Watson	2.101			
Diagnostics tests	Test-statistics	*p*-values		
χ^{LM-BG}	0.464	0.314		
χ^{ARCH}	0.573	0.380		
$\chi^{Ramsey\ reset}$	0.356	0.159		
$\chi^{Jarque-Bera}$	0.387	0.618		
CUSUM	Stable			
CUSUM-sq	Stable			

Statistical significance at the ***1%, **5%, and * 10% levels.
Author's Computation.

will decrease carbon emissions by 7.9% in the long run and 3.1% in the short run. This is very interesting and needs time where the world faces environmental degradation; it has been found that more innovative towards environmentally-friendly technologies will improve the environmental quality by decreasing the levels of CO_2 emissions (Meirun et al., 2021; Hu et al., 2022).

While focusing on the level of cointegration among drama and film industry (D&F) on CO_2 emissions, the (D&F) was reported to be positive and 1% level of significance in the long-run (β = 0.143, $p<$ 0.05) and positive and 5% level of significance in the short-run (β = 0.067, $p<$ 0.01). This means that a 1% increase in D&F will increase the CO_2 emissions by 14.3% in the long run and 06.7% in the short run. Thus, it has been proven that the drama and film industry consumes more energy in indoor and outdoor production, traveling, and post-production activities such as distribution and launching and cause high CO_2emissions. These results confirm the study results of the European broadcast union, which states that the world's audio-video sector is responsible for more than 2% of the total CO_2 emissions yearly (Ecopord.com). On the other hand, while focusing on the level of cointegration among GDP on CO_2 emissions, the GDP was reported to be positive and statistically significant at a 1% level in the long-run (β = 0.566, $p<$ 0.05) and positive and statistically significant at 1% level in the short-run (β = 0.231, $p<$ 0.01). It means that a 1% increase in GDP will increase carbon dioxide emissions by 56.6% in the long-run and 23.1% in the short run, respectively. It shows that high economic growth causes damage to the environment by emitting more greenhouse gas emissions into the atmosphere. The rise in financial development or per capita income accelerates financial activity, non-renewable energy use, global warming, and environmental pollution, thus raising the risk of potential loss of ecosystems. This evidence is consistent with several studies, such as those (Baz et al., 2020; Sharif et al., 2020; Meirun et al., 2021; Murshed et al., 2021). Overall outcomes illustrated in Table 6 favor the BARDL approach to express the dynamic relationship between variables.

TABLE 7 Granger causality results.

Null-hypothesis	F-statistics	*p*-value
GI does not Granger Cause CO_2	10.036***	0.000
CO_2 does not Granger Cause GI	4.233*	0.043
D&F does not Granger Cause CO_2	6.267***	0.000
CO_2 does not Granger Cause D&F	15.681***	0.000
GDP does not Granger Cause CO_2	16.433***	0.000
CO_2 does not Granger Cause GDP	2.579	0.318

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

In addition to these, while evaluating the model's predictability, all three predictors can explain the carbon emissions by 78%, which is referred to as the explanation of the variation in the criterion variable reflected by the value of R-square. Apart from that, the model was also reported to be free from autocorrelation, which is gauged by the measure of Durbin Watson. Lastly, while assessing the robustness and rigorousness of the model, the values of CUSUM and CUSUMsq clearing reflects that the model is legitimate and appropriate in terms of stability. All of the aforementioned statistical measures are also reported in Table 6.

Table 7 reports the results of the granger causality test. In the short-run, this study has found bidirectional causal links between drama and the film industry and carbon emissions (D&F$\leftrightarrow CO_2$) and between green innovation and carbon emissions (GI$\leftrightarrow CO_2$). We have also found a unidirectional causality from economic growth to carbon emissions (GDP$\rightarrow CO_2$).

Conclusion and policy implications

Environmental researchers have urged safeguarding nature, fauna, and flora, whereas if neglected, there will be abnormalities in the rainfalls, droughts, storms, etc. That is also expected to be more lethal and destructive because of the imbalance caused to the environment. Among the few potential solutions that could contribute to environment conservation by eliminating pollution is to create awareness among the masses and public, for which the potential of the role and the significance of contribution by the film and drama industry cannot be ignored.

The Indian drama and film industries are responsible for contributing efficiently to a sustainable environment. Hence, it is crucial to assess the influence of the drama and film industry, per capita GDP, and green innovation on CO_2 emission in India. No previous research has studied the drama and film industry's effect on CO_2 emissions. Nevertheless, the audio and visual industries are well-known for waste generation and excess energy sources. This study has covered the gap by applying the BARDL approaches to identify the dynamic relationship between GI, D&F, GDP, and CO_2 emissions. The study used the yearly data of variables from 2000 to 2020; before using the BARDL approach study, stationarity tests of ZA test with a structural break to find the integration order of the observations. The test outcomes indicate that all the observations are stationarity in 1st order. The results of the bootstrap ARDL can be used to identify the existence of cointegration between variables.

Moreover, the BARDL long and short-run dynamic approach results show the response of the endogenous variable against each exogenous variable's negative and positive variation. The green innovation (GI) was reported to be negative and statistically significant at a 5% level in the long-run and negative and statistically significant at a 1% level in the short run. The drama and film industry (D&F) was reported to be positive and statistically significant at a 1% level in the long run and positive and statistically significant at a 5% level in the short run. In contrast, economic growth (GDP) was reported to be positive and statistically significant at a 1% level in the long and short run. While comparing the beta parameters, economic growth was reported to be a higher predictor of a sustainable environment, followed by the drama and film industry and green innovation. This sector contributes to the Indian economy. Furthermore, the Granger causality test results reveal that green innovation, drama and the film industry have a bidirectional causal link with carbon emissions.

This paper offers several policy recommendations for reducing CO_2 emissions in several Indian economic sectors. Concerning Indian environmental policies for the industrial and manufacturing sectors, these sectors are hugely dependent on fossil fuel-based energy. Shifting to renewable energy sources, such as solar, gas, and coal-based energy as the primary energy sources is strongly recommended. Second, the government should improve environmentally friendly, long-term policy frameworks for manufacturing and industrial sectors to instigate like policies in related sectors. These measures and policy structures may also help improve management capability, foster public awareness of energy efficiency, and support green technology in the industrial sector. Third, India has been attempting to mandate an environmentally friendly industry and means for renewable energy and efficient energy policy but still has not achieved the target level. Fourth, the country should reduce CO_2 emissions through renewable energy efficiency; for example, a study of neighboring countries, Shao et al., 2022 and Shahzad et al., 2022, analyzed that technological progress in the various sectors of China, particularly for industrial (drama and film) and agriculture sectors are feasible for economic growth and CO_2 emissions reduction.

The green technological approaches include green filming, a resource-efficient concept to provide a sustainable contribution to climate change. Green filming controls the energy supply efficiently, transport, waste, and catering. The government should encourage green filming by introducing specific production houses and providing funding to fulfill the sustainable criteria. Furthermore, there is a need for knowledge sharing to create awareness and proper training in this industry to reduce environmental damage. Feature film production is time-consuming and resource-consuming; therefore, the green screen production process is highly suggested at every production stage; filmmakers can decrease the environmental impact of production activities. Filmmakers should emphasize paperless product planning, selection of closed sites and locations, reusable production materials, and minimal water and energy consumption. In the future, an overall review of all the world's leading film and theater industries will provide comprehensive countermeasures and suggestions for a concerted contribution to achieving sustainable environmental development goals. In addition, technological advances such as using hybrid vehicles for transportation, green screens or GGI boxes to reduce emissions, and using LED and solar power supply generators in manufacturing companies will positively impact the environment. Therefore, the general legal efforts of the government to improve the growing awareness and sustainable environment will green the film and drama sector.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

PD conceptualized, wrote the original draft, conducted the econometric analysis, and analyzed the findings; MA and UK compiled the literature review and generated the graphical illustrations, reviewed and edited the manuscript; MP and AK wrote the introduction and compiled the literature review and contributed to the methodology section; AK and SM supervised and reviewed the entire study. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

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

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References

Adedoyin, F. F., Gumede, M. I., Bekun, F. V., Etokakpan, M. U., and Balsalobre-lorente, D. (2020). Modeling coal rent, economic growth and CO_2 emissions: Does regulatory quality matter in BRICS economies? *Sci. Total Environ.* 710, 136284. doi:10.1016/J.SCITOTENV.2019.136284

Ahmad, M., Khan, Z., Ur Rahman, Z., and Khan, S. (2018). Does financial development asymmetrically affect CO_2 emissions in China? An application of the nonlinear autoregressive distributed lag (NARDL) model. *Carbon Manag.* 9 (6), 631–644. doi:10.1080/17583004.2018.1529998

Ahmed, W., Najmi, A., and Ikram, M. (2020). Steering firm performance through innovative capabilities: A contingency approach to innovation management. *Technol. Soc.* 63, 101385. doi:10.1016/J.TECHSOC.2020.101385

Alam, M. M., Murad, M. W., Noman, A. H. M., and Ozturk, I. (2016). Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecol. Indic.* 70, 466–479. doi:10.1016/J.ECOLIND.2016.06.043

Alam, M. S., Alam, M. N., Murshed, M., Mahmood, H., and Alam, R. (2022). Pathways to securing environmentally sustainable economic growth through efficient use of energy: A bootstrapped ARDL analysis. *Environ. Sci. Pollut. Res.* 1, 1–15. doi:10.1007/s11356-022-19410-9

Alam, M. S. (2022). Is trade, energy consumption and economic growth threat to environmental quality in Bahrain–evidence from VECM and ARDL bound test approach. *Int. J. Emerg. Serv.* Ahead of print. doi:10.1108/IJES-12-2021-0084

Alshehry, A. S., and Belloumi, M. (2017). Study of the environmental Kuznets curve for transport carbon dioxide emissions in Saudi Arabia. *Renew. Sustain. Energy Rev.* 75, 1339–1347. doi:10.1016/J.RSER.2016.11.122

Atici, C. (2009). Carbon emissions in central and eastern Europe: Environmental kuznets curve and implications for sustainable development. *Sust. Dev.* 17 (3), 155–160. doi:10.1002/sd.372

Baz, K., Xu, D., Ali, H., Ali, I., Khan, I., Khan, M. M., et al. (2020). Asymmetric impact of energy consumption and economic growth on ecological footprint: Using asymmetric and nonlinear approach. *Sci. Total Environ.* 718, 137364. doi:10.1016/J.SCITOTENV.2020.137364

Biresselioglu, M. E., Nilsen, M., Demir, M. H., Røyrvik, J., and Koksvik, G. (2018). Examining the barriers and motivators affecting European decision-makers in the development of smart and green energy technologies. *J. Clean. Prod.* 198, 417–429. doi:10.1016/J.JCLEPRO.2018.06.308

Brereton, P. (2014). Eco-cinema, sustainability and africa: A reading of out of africa (1985), the constant gardener (2005) and district 9 (2010). *J. Afr. Cinemas* 5 (2), 219–235. doi:10.1386/jac.5.2.219_1

Chandia, K. E., Gul, I., Aziz, S., Sarwar, B., and Zulfiqar, S. (2018). An analysis of the association among carbon dioxide emissions, energy consumption and economic performance: An econometric model. *Carbon Manag.* 9 (3), 227–241. doi:10.1080/17583004.2018.1457930

Chen, X., and Valdmanis, V. (2019). The content analysis of Chinese media report on the issue of waste incineration power plants. *Manag. Environ. Qual. Int. J.* 30 (2), 456–466. doi:10.1108/MEQ-05-2018-0091

Collins, M., Knutti, R., Arblaster, J., Dufresne, J. L., Fichefet, T., Friedlingstein, P., et al. (2013). "Long-term climate change: Projections, commitments and irreversibility," in *Climate change 2013-the physical science basis: Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change* (Cambridge University Press), 1029

Corbett, C. J. (2006). *Sustainability in the motion picture industry: Contractor's Report to the board (No. 440)*. Integrated Waste Management Board.

Dong, B., Zhang, M., Mu, H., and Su, X. (2016). Study on decoupling analysis between energy consumption and economic growth in Liaoning Province. *Energy Policy* 97, 414–420. doi:10.1016/J.ENPOL.2016.07.054

Du, K., and Lin, B. (2015). Understanding the rapid growth of China's energy consumption: A comprehensive decomposition framework. *Energy* 90, 570–577. doi:10.1016/J.ENERGY.2015.07.079

Feng, J., and Yuan, J. (1984). Effect of technology innovation and spillovers on the carbon intensity of human well-being. *SpringerPlus* 5, 346. doi:10.1186/s40064-016-1984-0

Forster, P. M., Forster, H. I., Evans, M. J., Gidden, M. J., Jones, C. D., Keller, C. A., et al. (2020). Current and future global climate impacts resulting from COVID-19. *Nat. Clim. Chang.* 10, 913–919. doi:10.1038/s41558-020-0883-0

Ganda, F. (2019). The impact of innovation and technology investments on carbon emissions in selected organisation for economic Co-operation and development countries. *J. Clean. Prod.* 217, 469–483. doi:10.1016/J.JCLEPRO.2019.01.235

Goh, S. K., Sam, C. Y., and McNown, R. (2017). Re-examining foreign direct investment, exports, and economic growth in Asian economies using a bootstrap ARDL test for cointegration. *J. Asian Econ.* 51, 12–22. doi:10.1016/J.ASIECO.2017.06.001

Grover, R. B. (2013). Green growth and role of nuclear power: A perspective from India. *Energy Strategy Rev.* 1 (4), 255–260. doi:10.1016/J.ESR.2012.12.010

Guo, X., Liang, C., Umar, M., and Mirza, N. (2022). The impact of fossil fuel divestments and energy transitions on mutual funds performance. *Technol. Forecast. Soc. Change* 176, 121429. doi:10.1016/J.TECHFORE.2021.121429

Hashmi, S. M., Bhowmik, R., Inglesi-Lotz, R., and Syed, R. (2022). Investigating the Environmental Kuznets Curve hypothesis amidst geopolitical risk: Global evidence using bootstrap ARDL approach. *Environ. Sci. Pollut. Res.* 29, 24049–24062. doi:10.1007/s11356-021-17488-1

He, Z., Xu, S., Shen, W., Long, R., and Chen, H. (2017). Impact of urbanization on energy related CO_2 emission at different development levels: Regional difference in China based on panel estimation. *J. Clean. Prod.* 140, 1719–1730. doi:10.1016/j.jclepro.2016.08.155

Heil, M. T., and Wodon, Q. T. (1997). Inequality in CO 2 emissions between poor and rich countries. *J. Environ. Dev.* 6 (4), 426–452. doi:10.1177/107049659700600404

Herrerias, M. J., Cuadros, A., and Orts, V. (2013). Energy intensity and investment ownership across Chinese provinces. *Energy Econ.* 36, 286–298. doi:10.1016/J.ENECO.2012.08.043

Hu, J., Xu, J., Tong, L., and Razi, U. (2022). The dynamic role of film and drama industry, green innovation towards the sustainable environment in China: Fresh insight from NARDL approach. *Econ. Research-Ekonomska Istraživanja* 1, 1–18. doi:10.1080/1331677X.2022.2026239

Hu, K., Raghutla, C., Chittedi, K. R., Zhang, R., and Koondhar, M. A. (2021). The effect of energy resources on economic growth and carbon emissions: A way forward to carbon neutrality in an emerging economy. *J. Environ. Manag.* 298, 113448. doi:10.1016/J.JENVMAN.2021.113448

Ielasi, F., Rossolini, M., and Limberti, S. (2018). Sustainability-themed mutual funds: An empirical examination of risk and performance. *J. Risk Finance* 19 (3), 247–261. doi:10.1108/JRF-12-2016-0159

İncekara, A., Şener, S., and Hobikoğlu, E. H. (2013). Economic evaluation of the film industry in terms of strategic management within the scope of the creative innovative industries: The case of Turkey. *Procedia - Soc. Behav. Sci.* 99, 636–647. doi:10.1016/J.SBSPRO.2013.10.534

Jaffe, A. B., Newell, R. G., and Stavins, R. N. (2002). *Environmental policy and technological change*. Environmental and Resource Economics, 22.

James, D. E., Jansen, H. M., and Opschoor, J. B. (2013). *Economic approaches to environmental problems: Techniques and results of empirical analysis*. Elsevier.

Jiang, Y., Zhou, Z., and Liu, C. (2019). Does economic policy uncertainty matter for carbon emission? Evidence from US sector level data. *Environ. Sci. Pollut. Res.* 26, 24380–24394. doi:10.1007/s11356-019-05627-8

Kasman, A., and Duman, Y. S. (2015). CO_2 emissions, economic growth, energy consumption, trade and urbanization in new eu member and candidate countries: A panel data analysis. *Econ. Model.* 44, 97–103. doi:10.1016/J.ECONMOD.2014.10.022

Khan, F, F., Ahmed, W., and Najmi, A. (2019). Understanding consumers' behavior intentions towards dealing with the plastic waste: Perspective of a developing country. *Resour. Conservation Recycl.* 142, 49–58. doi:10.1016/J.RESCONREC.2018.11.020

Khan, M. K, M. K., Teng, J. Z., Khan, M. I., and Khan, M. O. (2019). Impact of globalization, economic factors and energy consumption on CO_2 emissions in Pakistan. *Sci. Total Environ.* 688, 424–436. doi:10.1016/J.SCITOTENV.2019.06.065

Goh, S. K., Yee Yong, J., Lau, C., and Cheong, T. (2017). Bootstrap ARDL on energy-growth relationship for 22 OECD countries. *Appl. Econ. Lett.* 24 (20), 1464–1467. doi:10.1080/13504851.2017.1284980

Kraft, J., and Kraft, A. (1978). On the relationship between energy and GNP. *J. Energy Dev.* 3 (2), 401–403. https://about.jstor.org/terms.

Kumail, S, S., Rizvi, A., Mirza, N., and Rahat, B. (2020). Covid-19 and asset management in EU: A preliminary assessment of performance and investment styles. *J. Asset Manag.* 21, 281–291. doi:10.1057/s41260-020-00172-3

Kumail, T, T., Ali, W., Sadiq, F., Wu, D., and Aburumman, A. (2020). Dynamic linkages between tourism, technology and CO_2 emissions in Pakistan. *Anatolia* 31 (3), 436–448. doi:10.1080/13032917.2020.1742169

Lean, H. H., and Smyth, R. (2010). CO_2 emissions, electricity consumption and output in ASEAN. *Appl. Energy* 87 (6), 1858–1864. doi:10.1016/J.APENERGY.2010.02.003

Lopera-Mármol, M., and Jiménez-Morales, M. (2021). Green shooting: Media sustainability, A new trend. *Sustainability* 13 (6), 3001. doi:10.3390/su13063001

Lorek, S., and Spangenberg, J. H. (2014). Sustainable consumption within a sustainable economy – beyond green growth and green economies. *J. Clean. Prod.* 63, 33–44. doi:10.1016/J.JCLEPRO.2013.08.045

Malik, M. A. (2021). Economic growth, energy consumption, and environmental quality nexus in Turkey: Evidence from simultaneous equation models. *Environ. Sci. Pollut. Res.* 28, 41988–41999. doi:10.1007/s11356-021-13468-7/

Malmodin, J., and Lundén, D. (2018). The energy and carbon footprint of the global ICT and E&M sectors 2010-2015. *Sustainability* 10 (9), 3027–3031. doi:10.3390/su10093027

Manigandan, P., Alam, M. S., Alharthi, M., Khan, U., Alagirisamy, K., Pachiyappan, D., et al. (2021). Forecasting natural gas production and consumption in United States-evidence from SARIMA and SARIMAX models. *Energies* 14 (19), 6021. doi:10.3390/en14196021

McNown, R., Sam, C. Y., and Goh, S. K. (2018). Bootstrapping the autoregressive distributed lag test for cointegration. *Appl. Econ.* 50 (13), 1509–1521. doi:10.1080/00036846.2017.1366643

Meilani, M. (2021). Sustainability and eco-friendly movement in movie production. *IOP Conf. Ser. Earth Environ. Sci.* 794, 012075–075. doi:10.1088/1755-1315/794/1/012075

Meirun, T., Mihardjo, W. W., Haseeb, M., Abdul, S., Khan, R., and Jermsittiparsert, K. (2021). The dynamics effect of green technology innovation on economic growth and CO_2 emission in Singapore: New evidence from bootstrap ARDL approach. *Environ. Sci. Pollut. Res.* 28, 4184–4194. doi:10.1007/s11356-020-10760-w/

Mohsin, M., Kamran, H. W., Atif Nawaz, M., Sajjad Hussain, M., and Dahri, A. S. (2021). Assessing the impact of transition from non-renewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies. *J. Environ. Manag.* 284, 111999. doi:10.1016/J.JENVMAN.2021.111999

Murshed, M., and Alam, M. (2021). Estimating the macroeconomic determinants of total, renewable, and non-renewable energy demands in Bangladesh: The role of technological innovations. *Environ. Sci. Pollut. Res. Int.* 28, 30176–30196. doi:10.1007/s11356-021-12516-6/

Murshed, M., Mahmood, H., Ahmad, P., Rehman, A., and Alam, M. S. (2022). Pathways to Argentina's 2050 carbon-neutrality agenda: The roles of renewable energy transition and trade globalization. *Environ. Sci. Pollut. Res.* 29 (20), 29949–29966. doi:10.1007/s11356-021-17903-7

Murshed, M., Rahman, M. A., Alam, S., Ahmad, P., and Dagar, V. (2021). The nexus between environmental regulations, economic growth, and environmental sustainability: Linking environmental patents to ecological footprint reduction in South asia. *Environ. Sci. Pollut. Res.* 28, 49967–49988. doi:10.1007/s11356-021-13381-z/

Najmi, A., Kanapathy, K., and Azliza Aziz, A. (2021). Understanding consumer participation in managing ICT waste: Findings from two-staged structural equation modeling-artificial neural network approach. *Environ. Sci. Pollut. Res.* 28 (12), 14782–14796. doi:10.1007/s11356-020-11675-2/

Najmi, A., Maqbool, H., Ahmed, W., Aziz, S., and Rehman, U. (2020). The influence of greening the suppliers on environmental and economic performance. *Int. J. Bus. Perform. Supply Chain Model.* 11 (1), 69. doi:10.1504/ijbpscm.2020.108888

Nasir, M., and Ur Rehman, F. (2011). Environmental kuznets curve for carbon emissions in Pakistan: An empirical investigation. *Energy Policy* 39 (3), 1857–1864. doi:10.1016/J.ENPOL.2011.01.025

Neog, Y., and Kumar Yadava, A. (2020). Nexus among CO_2 emissions, remittances, and financial development: A NARDL approach for India. *Environ. Sci. Pollut. Res.* 27, 44470–44481. doi:10.1007/s11356-020-10198-0/

Nikzad, R., and Sedigh, G. (2017). Greenhouse gas emissions and green technologies in Canada. *Environ. Dev.* 24, 99–108. doi:10.1016/J.ENVDEV.2017.01.001

Ozturk, I., and Acaravci, A. (2010). CO_2 emissions, energy consumption and economic growth in Turkey. *Renew. Sustain. Energy Rev.* 14 (9), 3220–3225. doi:10.1016/J.RSER.2010.07.005

Ozturk, I., and Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Econ.* 36, 262–267. doi:10.1016/J.ENECO.2012.08.025

Pachiyappan, D., Ansari, Y., Alam, S., Thoudam, P., Alagirisamy, K., and Manigandan, P. (2021). Short and long-run causal effects of CO_2 emissions, energy use, GDP and population growth: Evidence from India using the ARDL and VECM approaches. *Energies* 14 (24), 8333. doi:10.3390/en14248333

Padilla-Pérez, R., and Gaudin, Y. (2014). Science, technology and innovation policies in small and developing economies: The case of Central America. *Res. Policy* 43 (4), 749–759. doi:10.1016/J.RESPOL.2013.10.011

Pao, H. T., and Tsai, C. M. (2010). CO_2 emissions, energy consumption and economic growth in BRIC countries. *Energy Policy* 38 (12), 7850–7860. doi:10.1016/J.ENPOL.2010.08.045

Pata, U. K. (2018). Renewable energy consumption, urbanization, financial development, income and CO_2 emissions in Turkey: Testing EKC hypothesis with structural breaks. *J. Clean. Prod.* 187, 770–779. doi:10.1016/J.JCLEPRO.2018.03.236

Pesaran, M. H., Shin, Y., and Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *J. Appl. Econ.* 16 (3), 289–326. doi:10.1002/jae.616

Rahman, M. M. (2020). Environmental degradation: The role of electricity consumption, economic growth and globalisation. *J. Environ. Manag.* 253, 109742. doi:10.1016/J.JENVMAN.2019.109742

Román-Collado, R., Cansino, J. M., and Botia, C. (2018). How far is Colombia from decoupling? Two-level decomposition analysis of energy consumption changes. *Energy* 148, 687–700. doi:10.1016/J.ENERGY.2018.01.141

Saboori, B., and Sulaiman, J. (2013). Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia. *Energy Policy* 60, 892–905. doi:10.1016/J.ENPOL.2013.05.099

Salami, S. A., Luciano, G., O'Grady, M. N., Biondi, L., Newbold, C. J., Kerry, J. P., et al. (2019). Sustainability of feeding plant by-products: a review of the implications for ruminant meat production. *Animal Feed Sci. Technol.* 251, 37–55. doi:10.1016/J.ANIFEEDSCI.2019.02.006

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

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., and Leitão, N. C. (2013a). Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. *Renew. Sustain. Energy Rev.* 25, 109–121. doi:10.1016/J.RSER.2013.04.009

Shahbaz, M., Raghutla, C., Song, M., Zameer, H., and Jiao, Z. (2020). Public-private partnerships investment in energy as new determinant of CO_2 emissions: The role of technological innovations in China. *Energy Econ.* 86, 104664. doi:10.1016/J.ENECO.2020.104664

Shahbaz, M., Solarin, S. A., Mahmood, H., and Arouri, M. (2013b). Does financial development reduce CO_2 emissions in Malaysian economy? a time series analysis. *Econ. Model.* 35, 145–152. doi:10.1016/J.ECONMOD.2013.06.037

Shahzad, U., Ferraz, D., Nguyen, H. H., and Cui, L. (2022). Investigating the spill overs and connectedness between financial globalization, high-tech industries and environmental footprints: Fresh evidence in context of China. *Technol. Forecast. Soc. Change* 174, 121205. doi:10.1016/J.TECHFORE.2021.121205

Shao, L., Xi, W., Saleem, F., Bajaber, N., and Abdul-Samad, Z. (2022). *The dynamic influence of inbound tourism and film and drama industry in promoting environmental sustainability in China: New evidence from bootstrap ARDL approach.* Economic Research-Ekonomska Istraživanja, 1

Shao, X., Zhong, Y., Liu, W., and Li, R. Y. M. (2021). Modeling the effect of green technology innovation and renewable energy on carbon neutrality in N-11 countries? Evidence from advance panel estimations. *J. Environ. Manag.* 296, 113189. doi:10.1016/j.jenvman.2021.113189

Sharif, A., Baris-Tuzemen, O., Uzuner, G., Ozturk, I., and Sinha, A. (2020). Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: Evidence from Quantile ARDL approach. *Sustain. Cities. Soc.* 57, 102138. doi:10.1016/J.SCS.2020.102138

Sheldon, T. L. (2017). Asymmetric effects of the business cycle on carbon dioxide emissions. *Energy. Econ.* 61, 289–297. doi:10.1016/J.ENECO.2016.11.025

Shu, X., Li, M., Ma, Z., and Qureshi, M. A. (2022). The asymmetric effect of film and drama industry, energy efficiency and economic growth on green innovation: Empirical evidence from quantile estimation. *Econ. Research-Ekonomska Istraz.*, 1–18. doi:10.1080/1331677X.2022.2032784

Sinha, A., and Shahbaz, M. (2018). Estimation of environmental kuznets curve for CO_2 emission: Role of renewable energy generation in India. *Renew. Energy* 119, 703–711. doi:10.1016/j.renene.2017.12.058

Song, X., Zhou, Y., and Jia, W. (2019). How do economic openness and R&D investment affect green economic growth?—evidence from China. *Resour. Conservation Recycl.* 146, 405–415. doi:10.1016/J.RESCONREC.2019.03.050

Stocchero, A., Seadon, J. K., Falshaw, R., and Edwards, M. (2017). Urban equilibrium for sustainable cities and the contribution of timber buildings to balance urban carbon emissions: A New Zealand case study. *J. Clean. Prod.* 143, 1001–1010. doi:10.1016/J.JCLEPRO.2016.12.020

Su, C. W., Khan, K., Umar, M., and Zhang, W. (2021). Does renewable energy redefine geopolitical risks? *Energy Policy* 158, 112566. doi:10.1016/J.ENPOL.2021.112566

Sun, Y., Razzaq, A., Sun, H., and Irfan, M. (2022). The asymmetric influence of renewable energy and green innovation on carbon neutrality in China: Analysis from nonlinear ARDL model. *Renew. Energy* 193, 334–343. doi:10.1016/j.renene.2022.04.159

Tiwari, A. K., Shahbaz, M., and Adnan Hye, Q. M. (2013). The environmental Kuznets curve and the role of coal consumption in India: Cointegration and causality analysis in an open economy. *Renew. Sustain. Energy Rev.* 18, 519–527. doi:10.1016/J.RSER.2012.10.031

Tsaurai, K. (2019). The impact of financial development on carbon emissions in Africa. *Int. J. Energy Econ. Policy* 9 (3), 144–153. doi:10.32479/ijeep.7073

Victory, J. (2014). *Green shoots: The role of eco-manager in sustainable film production*. (doctoral dissertation, doctoral thesis]. Staffordshire University.

Wang, K. H., Umar, M., Akram, R., and Caglar, E. (2021). Is technological innovation making world "greener"? An evidence from changing growth story of China. *Technol. Forecast. Soc. Change* 165, 120516. doi:10.1016/J.TECHFORE.2020.120516

Wang, R., Moreno-Cruz, J., Caldeira, K., Hu, X., Sun, Y., Liu, J., et al. (2019). The impact of environmental protection tax on sectoral and spatial distribution of air pollution emissions in China. *Environ. Res. Lett.* 14, 054013–013. doi:10.1088/1748-9326/ab1965

Weina, D., Gilli, M., Mazzanti, M., and Nicolli, F. (2016). Green inventions and greenhouse gas emission dynamics: A close examination of provincial Italian data. *Environ. Econ. Policy Stud.* 18, 247–263. doi:10.1007/s10018-015-0126-1

Wu, H., Li, Y., Hao, Y., Ren, S., and Zhang, P. (2020). Environmental decentralization, local government competition, and regional green development: Evidence from China. *Sci. Total Environ.* 708, 135085. doi:10.1016/J.SCITOTENV.2019.135085

Wu, Y. (2012). Energy intensity and its determinants in China's regional economies. *Energy Policy* 41, 703–711. doi:10.1016/J.ENPOL.2011.11.034

Yu, B., Li, C., Mirza, N., and Umar, M. (2022). Forecasting credit ratings of decarbonized firms: Comparative assessment of machine learning models. *Technol. Forecast. Soc. Change* 174, 121255. doi:10.1016/J.TECHFORE.2021.121255

Zhang, J., Terrones, M., Park, C. R., Mukherjee, R., Monthioux, M., Koratkar, N., et al. (2016). Carbon science in 2016: Status, challenges and perspectives. *Carbon* 98, 708–732. doi:10.1016/J.CARBON.2015.11.060

Zhou, X., Zhang, M., Zhou, M., and Zhou, M. (2017). A comparative study on decoupling relationship and influence factors between China's regional economic development and industrial energy–related carbon emissions. *J. Clean. Prod.* 142, 783–800. doi:10.1016/J.JCLEPRO.2016.09.115