Accountancy Business and the Public Interest
ISSN: 1745-7718
Volume: 40
Issue Number:05

REDUCING EMISSIONS IN INDIA: ACCOUNTING THE IMPACT OF INCOME, RENEWABLE ENERGY, AND ENERGY SOURCES

PREETI SLATHIA[1]* and Dr. ASHUTOSH VASHISHTHA[2]

[*1]School of Business, Department of Management, Shri Mata Vaishno Devi University, India.
Email:19dbu009@smvdu.ac.in.
[2]Professor, School of Business, Department of Management, Shri Mata Vaishno Devi University, India.
Email: ashu.vashishtha@smvdu.ac.in

Abstract

The pursuit of environmental sustainability has emerged as a worldwide imperative, specifically in the context of mitigating climate change. The primary emphasis of this study is India, a highly industrialized nation that is a substantial contributor to carbon dioxide emissions. The present study investigates the influence of renewable and non-renewable energy sources, economic growth, and investment in the energy sector on carbon dioxide (CO2) emissions. By employing several regression techniques and Granger causality analysis, the study reveals a negative correlation between renewable energy and CO2 emissions, indicating its capacity for promoting sustainable growth. Nevertheless, there exists a favorable association between non-renewable energy and real GDP growth in regard to CO2 emissions. Additionally, the study demonstrates a unidirectional causal relationship between the consumption of renewable energy and the levels of CO2 emissions, economic development, and energy investment. The implications derived from the study's findings have significant importance for policymakers seeking to advance environmental sustainability within the Indian economy. The observed inverse correlation between carbon dioxide (CO2) emissions and the utilization of renewable energy implies that implementing policies that encourage the adoption of renewable energy sources may prove efficacious in mitigating carbon emissions and attaining sustainability objectives.

Key words: Environment, Sustainability, Econometrics, India.

INTRODUCTION

Environmental sustainability has become a top priority for the worldwide society in response to the urgent problem of climate change. Although non-renewable energy sources have traditionally played a crucial role in stimulating economic growth, there is an increasing acknowledgment of the necessity to shift towards sustainable energy sources as a result of the environmental repercussions linked to the utilization of fossil fuels. The emphasis on sustainable energy production has been emphasized by technological developments and increased endeavors in environmental preservation. Wind, solar, and hydro power are increasingly recognized as viable alternatives to conventional non-renewable energy sources. Nevertheless, there is a notable lack of widespread implementation of clean energy solutions in both developing and established economies, despite the increasing worldwide need for the shift towards sustainable and low-carbon energy alternatives. The sentiment expressed by the Intergovernmental Panel on Climate Change (IPCC) aligns with the imperative of transitioning from non-renewable fossil fuel sources to sustainable energy alternatives in order to address the consequences of climate change. The aforementioned transition holds significant importance in facilitating economic progress within emerging markets. Previous research conducted by scholars such as Apergis and Payne (2012) has emphasized the significance of studies investigating the correlation between sustainable and non-renewable energy sources and economic growth. These studies offer valuable insights that can inform the development of inclusive growth strategies and sustainable energy policies. Over time, multiple studies have attempted to evaluate the influence of different factors, such as the use of renewable energy, consumption of fossil fuels, and sustainable development, on the deterioration of the environment. Nevertheless, the current body of literature has yet to establish a unanimous agreement regarding these associations. The objective of this study is to fill this void by amalgamating results from multiple pertinent investigations. An autoregressive Global Lag Cointegration technique was employed by Belaid and Youssef (2017) to examine the complex causal connections between CO2 emissions, electricity generation, fossil-based power consumption, and sustainable growth in Algeria during the period of 1980 to 2012. The study revealed that over an extended period, income activities and excessive electricity consumption have a detrimental effect on climate development, whereas the adoption of renewable energy sources yields positive outcomes. In a similar vein, Ito (2017) conducted an analysis using panel data from 42 developed nations covering the period from 2002 to 2011. The objective was to investigate the relationship between CO2 emissions, the utilization of clean and non-renewable energy sources, and the promotion of sustainable development. Their findings demonstrated that the utilization of non-renewable energy sources has detrimental impacts on the progress of sustainable development in industrialized countries, but the adoption of green energy sources has a beneficial influence on future sustainable development. In their study, Boontome et al. (2017) employed cointegration and causality approaches to investigate the causal connections among fossil fuel, clean energy, emissions, and sustainable development in Thailand throughout the period of 1971 to 2013. Cointegration was identified among the variables, revealing a unidirectional causal relationship between fossil fuel consumption and emissions. This finding suggests that the utilization of fossil fuels in Thailand leads to an increase in emissions. In addition, Inglesi-Lotz and Dogan (2018) examined the factors that affect CO2 emissions in the ten main oil-producing countries in Sub-Saharan Africa between 1980 and 2011, in order to resolve inconsistencies in the existing literature. A long-term correlation was established between components, revealing that higher emissions are associated with increased usage of non-renewable energy, whereas sustainable energy has the reverse effect. Bekun et al. (2019) conducted a study in which they employed structured panel data spanning from 1996 to 2014 to investigate the correlation between greenhouse gas emissions, productivity growth, natural resource rent, sustainable energy, and non-renewable energy consumption within a specific group of EU-16 member states. The results of their study indicated a robust and enduring association between a nation's natural resource rent and carbon dioxide emissions, so emphasizing that excessive dependence on natural resource rent has adverse effects on endeavors aimed at environmental conservation. Additionally, it was observed that the utilization of non-renewable energy sources and the level of corporate output contribute to the escalation of greenhouse gas emissions, whereas the adoption of sustainable energy sources leads to a reduction in carbon dioxide emissions. Furthermore, a study conducted by Chen et al. (2019a) examined the relationship between per capita carbon dioxide (CO2) emissions, gross domestic product (GDP), sustainable energy, non-renewable energy, output, and international trade in China throughout the period of 1980 to 2014. Their research uncovered a persistent correlation among these characteristics. It is worth mentioning that the researchers made an observation that China did not demonstrate an Environmental Kuznets Curve (EKC) in relation to its output and carbon emissions. Their extended forecasts revealed that the utilization of fossil fuels and the expansion of GDP are factors that contribute to pollution, but the implementation of clean energy and international commerce have detrimental effect on carbon emissions. The researchers conducted a short-term Granger causality study to examine the relationship between international trade, CO2 emissions, fossil fuel usage, and clean energy. Their findings revealed a bidirectional causation, emphasizing the significance of adopting green energy sources as a means to address CO2 pollution in the long run. The aim of this study is to examine how the use of clean energy and fossil fuels affects environmental sustainability goals in India. This will be achieved by including energy investments into the empirical framework. The present study is based on a carbon-income function, using supplementary variables to emphasize the factors influencing carbon emissions, particularly in the context of India. The inclusion of these supplementary variables serves to mitigate any potential biases that may arise from the exclusion of certain variables in the econometric modeling process. The selection of India as the subject of this study is driven by its position as one of the largest and most rapidly developing countries in terms of energy dependence worldwide, with a substantial dependence on global fossil fuel resources. However, it is worth noting that India's use of clean energy per person is rather low in comparison to other developing nations. Nevertheless, it is anticipated that there will be a significant rise in the near future as a result of endeavors to enhance the standard of living and the swift growth of the industrial sector under existing regulations. The region is anticipated to experience growth in energy production; nevertheless, the heightened level of competitiveness may provide certain obstacles. Therefore, it is expected that India's reliance on imported resources would continue to increase in the future. India's socio-economic progress could be hindered by severe energy shortages caused by unpredictable topographical conditions, which could disrupt fossil fuel supplies. This study utilizes Fully Modified Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegrating Regression (CCR) methodologies to investigate the enduring elasticity and causal connections among the adoption of clean energy, utilization of fossil fuels, and economic growth in India. The present study is organized in the following manner: In this section, the data and technique utilized are presented, followed by an analysis of the empirical findings in Section 3. Section 4 serves as the final section of the study and provides policy implications.

LITERATURE REVIEW

Relationship between Renewable Energy consumption and Carbon emissions:

The body of research demonstrates that, over a few decades, RE usage is commonly recognized as a major impediment to rising CO2 emissions. Global researchers have been putting extensive efforts for providing sustainable solutions at local and government level. (Jiang et al., 2022) suggested that, by employing the FMOLS and DOLS approaches, RE consumption assists APEC nations in reducing their CO2 emissions. (Inglesi-Lotz and Dogan, 2018) found the effect of clean and nonclean energy on CO2 over a period of 1980-2011 in Sub-Saharan African region. (Dong et al., 2018) examined the relationship, globally, between emissions of carbon and energy efficiency in 120 countries between 1995 and 2015. The study found that there are considerable regional differences in the pace at which CO2 are being reduced. (Shahzad et al., 2021) employing the Feasible Generalized Least Square and Fully Modified Ordinary Least Square methodologies to determine the significance of RE consumption as a function of product diversification in the G7 and E7 countries between 1971 and 2014. (Mehmood et al.,2021) on the same subject reduction in CO2 by RE in G 11 economies. Moreover, these nations can also achieve Sustainable Development Goals. (Dogan and Seker, 2016b) and (Ansari, Haider and Khan, 2020) highlighted the importance of RE Consumption for escalating efficiency and improvement in eco-sustainability using FMOLS and DOLS techniques.

There exists a little body of research on consumption-based CO2 and RE.The first and foremost study was supported by (Wiebe, 2016) who found two ways to bring down CO_2. Reducing the amount of products and services used can help reduce CO2 emissions. Another strategy is to switch to products that produce less carbon dioxide and reduce the amount of emissions from production operations. This can be achieved by switching to clean energy, especially in manufacturing industries all over the globe. (Ding, Khattak and Ahmad, 2021b) research on G7 countries over 1990-2018 found out thar using RE reduces CO2 emissions. Table 2 offers a summary of the key findings of some other studies on this section.

Table 1: Summary of Studies On Re Consumption and Co2 Nexus

Author	Methodology	Country	Time	Key Findings
(Rehman et al., 2021)	Method Moments Quantile Regression	Asian Countries	1996-2014	The study evidences that REC negatively impacts CO2 emissions.
(Ramzan et al., 2022)	Non-Parametric Causality	Pakistan	1960-2019	The findings reported CO2 in the atmosphere are increased by the rapid expansion in RE.
(Z. Khan et al., 2020)	Panel Co-integration Analysis	G-7 Countries	1990-2017	The study demonstrated that Emissions of carbon are adversely correlated with RE.
(Sun, Bao, et al., 2022)	Methods of Moments Quantile	BRICS	1995-2018	The following research reveals that, by maximizing CO2 may be decreased by the use of RE sources.
(L. Du et al., 2022)	DOLS, FMOLS	MINT Countries	1990-2018	The mentioned study reflects presence of EKC and pollution havens leading to reduce CO2 through the use of RE.
(Sun, Li, et al., 2022)	Panel Estimation Techniques	MENA Economies	1991-2019	Consuming RE is the greatest way to reduce CO2, as per the study.
(Kirikkaleli et al., 2022)	ARDL, FMOLS, DOLS	Chile	1990-2017	This research signifies that Utilizing RE sources can result in a significant decrease in CO2.
(Ali et al., 2021)	ARDL	Top 10 Carbon Emitters Countries	1990-2017	Negative corelation between RE Consumption and CO2.
(Adebayo & Rjoub, n.d.-a)	CS-ARDL	MINT Nations	1990-2017	The author explains the decrease in level of CO2 due to Renewable Consumption of Energy.
(Kirikkaleli et al., n.d.)	Maki-Cointegration, Bayer Hanck Co-integration, FMOLS	India	1990-2015	Ultimately, using RE can help reduce CO2 over time.
(Adebayo & Kirikkaleli,2021)	Wavelet Analysis	Japan	1990-2015	Short-term CO2 are greatly decreased by the use of RE.
(Adebayo et al., n.d.)	ARDL, DOLS, Gradual Shift, Causality Test	Brazil	1990-2018	More utilization of clean energy leads to emit emissions from the environment, Additionally, the switch to RE from fossil fuels opens up new avenues for sustainable solutions.

Relationship between GDP and Carbon emissions:

(Halicioglu, 2009) analysed the bi-directional connection between EG (EG) and CO2 emissions in Turkey during the period 1960-2005. The findings showed parametric stability between CO2 and EG. (Omri, Ben Mabrouk and Sassi-Tmar, 2015) studied EG and CO2 in 17 developed and developing economies from 1990 to 2011, and explored that there is a bi-directional relationship between the two variables for the globe. (Omri et al., 2015) discovered bi-directional causality between CO2 and EG, the neutral hypothesis was found in the case of CO2 and financial development. The empirical findings will help to sustain EG and environmental quality in the future. For 193 countries, (Khan et al., 2019) found that economic development leads to increased CO2 and environmental degradation using the time 1990-2017.

According to (Soytas and Sari, 2009) there is an absence of a long-run relationship between EG and CO2 emissions leading to diminishing CO2 in the near future using Granger Causality analysis in Turkey. As per (Arouri et al., 2012), there exists a two-way causality between EG and and CO2 over a time period of 1981-2005 using bootstrap panel unit root tests and co-integration techniques in MENA countries. Similar findings observed (Richmond and Kaufmann, 2006) between income and CO2 in OECD nations for 1973-1997. The study by (Mikayilov, Galeotti and Hasanov, 2018) identifies two-way causality between the two variables in Azerbaijan during 1992-2013 by employing DOLS and FMOLS. Uniformly, a study (Tsaurai, 2019) finds a positive bi-directional relationship between EG and CO2 in Africa from 2003-2014. (Wang and Wang, 2019) stressed decoupling economic development and CO2 by using the decoupling effort model in the United States from 1997-2015. The following study uses R&D expenditure for data restriction.

(Odhiambo, 2012) found a direct flow of economic development. Also, the results showed a unidirectional relationship between them. (Azomahou, Laisney and Nguyen Van, 2006) who studied the link between EG and CO_2 emissions for 100 countries from 1960 to 1996, shows a linear relationship among the variable and presence of EKC. Similarly, (Shafik, 1994) also showed a linear linkage between economic development and environmental quality.

The validity of the EKC theory (Environmental Kuznets Curve) is also examined in relation to GDP and CO2. Existing research on the topic has suggested that there is an inverse U-shaped linkage between the degree of environmental degradation and GDP. This linkage has been examined by (Grossman1991; Selden1994,) who suggested that initially, EG causes environmental deterioration however, environmental quality gradually improves after attaining a certain level of economic progress to render an inverted U shape relationship between EG and environmental destruction. Various researchers present a variety of contradictory findings (Stern, Common and Barbier, 1996), (Saboori, Sulaiman and Mohd, 2012), (Ozturk and Acaravci, 2010), (Jaunky, 2011), (Ekins, 1997), (Managi and Jena, 2008),(Fodha and Zaghdoud, 2010) and (Heil and Selden, 1999) indicating this relationship is highly perplexing. For instance, (Dinda, 2004) investigates the plethoric existing literature of EKC and revealed, in the initial phase, the environmental quality diminishes with the pace of highly increasing EG and after that gradually slows down in the latter stage forming an inverted U-shaped curve. It also asserts that people with a high standard of living will prefer eco-friendly technologies leading to improvising environmental quality. A recent study (Acheampong, 2018) which employed System GMM analysis for 116 countries from 1960-2014 identifies economic development as a way to mitigate CO2. There is evidence of EKC at the global level. (Shoaib et al., 2020) also stressed in the same agenda using ARDL and panel unit root tests for developing countries and developed countries where GDP particularly reduces CO2 at 1%. (Narayan, Saboori and Soleymani, 2016) investigations showed 12% of sample countries support EKC. Various academics and policymakers suggest that the excessive usage of particular emissions will limit EG, while the decoupling technique suggests substantial reductions in CO2 without compromising economic development (Kirikkaleli, Güngör and Adebayo, 2022).

There is an emerging research topic with a recently introduced consumption-based CO2 measure. Although the interrelation between consumption-based CO2 and other economic variables is not well investigated. One of the earliest researched by (Knight and Schor, 2014) who identified the link between CO2 and EG over 1990-2008 for the 29 high income countries. The author found positive relationship between them, also the effect of territorial and consumption-based CO2 (CE) are more than territorial CE. (Safi et al., 2021) described the nexus between growth and consumption-based CE in E7 nations, asserts that economic development accords CO2. Similarly, (Adebayo and Rjoub, no date) identifies the relationship between growth and consumption-based CO2 also discussed that EG enhances the growth of consumption-based CO2 in MINT economies. Likewise, Researchers like (Jian et al., 2019) and (Hasanov, Liddle and Mikayilov, 2018a) also reveals positive linkage between growth and consumption-based CE in case of 14 major economies and nine oil exporting countries. The upsurge in income leads to increase in consumption-based CO2. Table 3 offers a summary of the key findings of some other studies in this section.

Table 2: An Overview of the relationship between GDP and CO2

Author	Methodology	Country	Time	Key Findings
(Magazzino, 2016a)	Co-integration Techniques, ARDL	GCC Countries	1960-2013	The study supports a neutral linkage between CO2 and EG. Furthermore, the causality results revealed that dynamic and diversified energy policies should be implemented.
(Magazzino, 2014)	Panel VAR, IFR	ASEAN	1971-2007	Direct relationship between EG and CE.
(Narayan & Narayan, 2010b)	Panel Co-integration Techniques	43 Developing Nations	1980-2004	The author investigated the link between CO2 and GDP and explains the increasing rate of EG accords more emissions, particularly CO2.
(Zhang et al., 2014b)	ARDL	China	1978-2011	GDP plays a significant role in reducing CO2 but escalates population growth which in turn increases CO2 intensity. However, Environment growth is one of the main drivers for the rapidly changing velocity of CO2.
(B. Dong et al., 2016)	EKC, OLS	Globally	1990-2012	The following study implied that EKC has a linear association with consumption-based emissions.
(M. K. Khan et al., 2020)	ARDL Estimates	Pakistan	1965-2015	In the long term, GDP escalates CO2, further, there is a dire need of replacing the old fossil fuels with clean energy for a sustainable environment.
(Adebayo et al., 2021)	Wavelet Analysis	Japan	1990-2015	long run, direct relationship between EG and CE
(Solarin et al., 2017)	ARDL	Ghana	1980-2012	GDP positively impacts CO2 while organizational quality assures a decrease in CO2.
(Magazzino, 2016b)	VAR, IRF	GCC countries	1992-2013	The results showed that GDP is significantly influenced by CO2. Also, CO2 negatively impact EG.
(Hens et al., n.d.)	Statistical Model	Belgium	1945-1990	The study suggests high EG leads to energy consumption which is the biggest contributor to increased CO2.
(Shabir et al., n.d.)	Panel Quantile Regression	24 Developed and Developing countries	2001-2019	Carbon dioxide plays a crucial role in maintaining a sustainable environment while EG policies negatively affect the atmosphere. The bi-directional relationship found between GDP and CO2.

METHODOLOGY

This study aims to examine the effects of both clean and non-renewable energy consumption on carbon dioxide (CO2) emissions within the Indian context. This analysis made use of data obtained from indicators provided by the World Bank. Carbon dioxide (CO2) emissions are widely regarded as a metric for assessing environmental deterioration, whereas the increase of gross domestic product (GDP), measured in 2010 US dollars, is utilized as an indicator of economic expansion and investment in the energy industry. The study specifically investigates the relationship between private investment in energy, assessed in current US dollars, and economic growth, calculated as GDP per capita in constant 2010 US dollars. The dataset encompasses the time period from 1990 to 2022, indicating the presence of pertinent data for study.

Theoretical Model:

The following model is utilized to analyze the influence of energy usage and non-renewable energy on CO2 emissions within a carbon-income framework:

The equation is CO2_t = f(REC_t, NREC_t, GDP_t, IEC_t).

In this context, the variable (CO2) represents carbon dioxide emissions measured in metric kilograms per unit. The variable (GDP) represents GDP growth. The variable (REC) represents renewable energy consumption as a percentage of total final energy consumption. The variable (NREC) represents fossil fuel energy consumption as a percentage of the total. The variable (GDP) signifies GDP per capita in constant 2010 US dollars. Lastly, the variable (IEC) represents investment in energy with private players in the market measured in current US dollars.

The current body of literature on the correlation between energy consumption and emission levels is quite scarce. However, this particular study aims to investigate the factors influencing carbon dioxide (CO2) emissions within the Indian economy. Furthermore, this study integrates investments in the energy industry as a means to replace trade transparency and urbanization, so setting it apart from prior research.

In order to conduct data analysis, a double log-linear transformation is applied to the variables in Equation (1). The time series' econometric specification is defined as follows:

The rate of change of CO2_t is equal to the sum of beta_0, beta_1, REC_t, beta_2, NREC_t, beta_3, GDP_t, beta_4, IEC_t, and mu_t.

RESULTS AND DISCUSSION

Table 3: Descriptive Statistics

	CO2	GDP	IEC	NREC	REC
Mean	0.1079	6.9290	21.328	4.1852	3.8367
Median	0.0912	6.8870	21.218	4.1834	3.90658
Max	0.2662	7.6511	24.264	4.3438	4.0717
Min	–0.0608	6.3554	16.415	3.9847	3.5319
Std. Dev	0.0993	0.4023	1.6031	0.1028	0.1771
Skewness	0.1119	0.2064	–0.5599	–0.2383	–0.3891

Table 4: Correlation Matrix analysis

	CO2	GDP	IEC	NREC	REC
CO2	1				
GDP	–0.9223***	1			
IEC	–0.594***	0.552***	1		
NREC	–0.846***	0.983***	0.595***	1	
REC	0.851***	–0.984***	–0.548***	–0.965***	1

***=0.01, **=0.05, *=0.10

Table 5: Unit root

Statistics	CO2	GDP	REC	NREC	IEC	
$\pi\tau$	–0.4475	2.8419	1.1732	–2.0602	–2.5155	
$\pi\vartheta$	–2.7397	–2.4749	–1.8323	–2.8045	–2.9581	

Statistics (FIRST DIFF)	CO2	GDP	REC	NREC	IEC
$\pi\tau$	–5.7743***	–4.8987***	–3.3449**	–4.9060***	–8.0548***
$\pi\vartheta$	–5.6346***	–5.4354***	–3.5434*	–5.1166***	–7.9485***

***=0.01, **=0.05, *=0.10.; thus, $\pi\tau$ is constant, $\pi\vartheta$ is constant and trend

Table 6: Johansen cointegration test

Hypothesis	Fisher stat	E- Value	P-value
CE	(trace)		
$r \leq 0$	97.983***	0.827204	(0.0001)
$r \leq 1$	50.581**	0.641360	(0.0261)
$r \leq 2$	22.895	0.358480	(0.2512)
$r \leq 3$	10.914	0.206607	(0.2269)
$r \leq 4$	4.6983	0.169710	(0.3402)

***=0.01, **=0.05 and *=0.10

Table 7: CCR, DOLS and FMOLS

Variables	CCR	DOLS	FMOLS
GDP	−0.9219***	−0.9500***	−0.9578***
P-value	(0.0000)	(0.0009)	(0.0000)
REC	−1.2398***	−1.1547***	−1.2519***
P-value	(0.0000)	(0.0037)	(0.0000)
NREC	0.7098***	1.0848**	0.8367***
P-value	(0.0017)	(0.0282)	(0.0055)
IEC	−0.0091**	−0.0034	−0.0082**
P-value	(0.0442)	(0.8234)	(0.0152)
Constant	8.4856***	6.5467**	8.1595***
P-value	(0.0000)	(0.0127)	(0.0000)
R-SQUARE	0.967	0.9846	0.9667
ADJ R-SQUARE	0.959	0.9546	0.9493

***=0.01, **=0.05 and *=0.10

Table 8: Granger causality

Null hypothesis	F-Test	P-value
GDP≠CO2	1.567	(0.2312)
CO2≠GDP	0.005	(0.9953)
IEC≠CO2	0.141	(0.8699)
CO2≠IEC	0.723	(0.4967)
NREC≠CO2	2.422	(0.1121)
CO2≠NREC	1.193	(0.3223)
REC≠CO2	1.004	(0.3829)
CO2≠REC	3.402*	(0.0516)
IEC≠GDP	1.227	(0.3126)
GDP≠IEC	4.389**	(0.0249)
REC≠GDP	0.297	(0.7460)
REC≠GDP	2.404	(0.1138)
GDP≠REC	0.248	(0.7831)
GDP≠REC	2.716*	(0.0883)
NREC≠IEC	0.491	(0.6186)
IEC≠NREC	0.014	(0.9843)
REC≠IEC	1.043	(0.3693)
IEC≠REC	0.649	(0.5326)
REC≠NREC	1.198	(0.3203)
NREC≠REC	0.843	(0.4440)

***=0.01, **=0.05 and *=0.10. While≠denote does not "Granger cause"

This part provides a concise presentation and interpretation of the empirical findings. Table 1 demonstrates that carbon dioxide (CO2) emissions exhibit the highest magnitude across the duration of the investigation. With the exception of emissions and GDP, the majority of variables demonstrate negative skewness. A pairwise correlation analysis conducted by Pearson demonstrates a strong association between carbon dioxide (CO2) emissions and economic development, along with other macroeconomic variables that were taken into account.

In order to ascertain the stationarity of the variables utilized in this analysis, the Dickey-Fuller (ADF) test was employed. The researchers proceeded to do cointegration analysis in order to determine the enduring equilibrium relationship between the variables in Equation (2). In order to ascertain the cointegration qualities, the Johansen cointegration test was utilized. Furthermore, the Long-term elasticity of the variables was analyzed using Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Canonical Cointegrating Regression (CCR) approaches. Following this, a Granger Causality analysis was performed in order to examine the causative connections between the variables.

The results of the stationarity test, which is essential for assessing the integration properties of the variables being examined, are displayed in Table 2. To prevent false regression and misleading inferences, it is crucial to ensure that the variables are integrated of order 1, as working with variables that are integrated of order 2 may lead to such outcomes. The findings shown in Table 2 provide confirmation that the studied variables exhibit integration of order 1, suggesting stationarity following the use of first differencing. After receiving this confirmation, we will now examine the equilibrium characteristics of the series, as shown in Table 3. The findings of the Johansen cointegration test indicate that there is evidence of cointegration among the variables throughout the sampled period, supporting the presence of two cointegration vectors and rejecting the null hypothesis of no cointegration.

The long-run elasticity of the variables was evaluated in this work using different regression techniques, such as canonical cointegrating regression (CCR), completely modified least squares (FMOLS), and dynamic least squares (DOLS), as shown in Table 4. The findings indicate that there is a continuous negative correlation of 1% between renewable energy use and all three methodologies. Consequently, a 1% rise in the utilization of renewable energy would result in a reduction of emissions by about 1.24%, 1.15%, and 1.25% correspondingly. In contrast, the consumption of non-renewable energy exhibits a favorable and substantial influence in all simulations, suggesting that a 1% rise in non-renewable energy utilization will result in emissions escalating by about 0.71%, 1.08%, and 0.84% correspondingly. Moreover, there exists a noteworthy and adverse correlation between GDP and emissions, suggesting that a 1% rise in GDP would result in a reduction in emissions by around 0.91%, 0.94%, and 0.95% respectively over an extended period. This observation aligns with the conclusions drawn by Bekun et al. (2019). Moreover, it is noteworthy that there exists a substantial adverse effect of 5% on the estimations of both CCR and FMOLS with respect to investment in the energy sector. This implies that a 1% augmentation in investment in the energy sector would result in a reduction of emissions by about 0.0081% in CCR and 0.0082% in FMOLS.

After verifying the long-term responsiveness of the variables, Granger Causality analysis was performed to investigate the causative connections between the variables. The findings are displayed in Table 5, which demonstrates a unidirectional causal relationship between the usage of renewable energy and emissions, sustainable development and investment in the energy sector, and sustainable development and renewable energy utilization. The results of this study are consistent with the conclusions reported by Gyamfi et al. (2020), highlighting the significance of adopting cleaner energy technology as a means to advance sustainable development objectives.

CONCLUSION

This study aims to examine the complex correlation between the utilization of renewable energy, the consumption of non-renewable energy, economic expansion, investment in the energy industry, and carbon emissions in the Indian economy from 1990 to 2016. Utilizing data sourced from the World Bank indicators database, this study examines the dynamic process of industrialization in India, acknowledging the concomitant increase in human activities and emissions, which presents notable environmental obstacles. India, like other countries, is obligated to synchronize its actions with global accords like the Kyoto Protocol, emphasizing the necessity of decreasing emissions for a sustainable future.

The study utilizes a strong analytical framework that includes canonical cointegrating regression (CCR), Fully Modified Least Squares (FMOLS), and Dynamic Least Squares (DOLS) approaches to understand the complex dynamics involved. These methodologies enable a comprehensive analysis of the enduring elasticity of the variables being investigated. Furthermore, the application of Granger Causality analysis is employed to ascertain the causative connections between the variables, hence providing insights into the directional associations that influence emissions patterns within the Indian setting.

The regression results highlight important observations. A consistent pattern emerges across all estimations, indicating the significant significance of renewable energy usage in mitigating emissions. The exploitation of renewable energy is positively correlated with a significant decrease in emissions, so confirming the effectiveness of sustainable energy solutions in addressing environmental degradation. In contrast, the study demonstrates a direct relationship between the use of non-renewable energy and the release of emissions, emphasizing the detrimental impact on the environment caused by dependence on fossil fuels. Additionally, the methodology provides a clearer understanding of the impact of economic growth, as quantified by GDP, on emissions, which aligns with previous research outcomes. Furthermore, the allocation of resources towards the energy sector is identified as a crucial factor, exhibiting a noticeable adverse effect on emissions over an extended period. This highlights the potential of deliberate financial interventions in promoting sustainability.

The Granger Causality test reveals interesting patterns, demonstrating a one-way causative relationship between renewable energy consumption and emissions, sustainable development and investment in the energy sector, and sustainable development and renewable energy consumption simultaneously. The aforementioned findings highlight the necessity of implementing policy measures in India. The adoption of strategies such as the implementation of carbon reduction programs, the provision of tax incentives, and the allocation of financial resources to renewable energy enterprises are essential measures in promoting a more environmentally friendly and sustainable future. Furthermore, it is recommended to adopt a deliberate transition from conventional energy consumption reliant on fossil fuels to renewable alternatives, as these alternatives offer inherent environmental advantages and are in line with sustainability goals. Enhanced allocation of resources towards energy infrastructure, namely through cooperative collaborations between public and private sectors, has the potential to stimulate both ecological sustainability and economic advancement in India.

References

1. Adedoyin, F.F., Gumede, M.I., Bekun, F.V., Etokakpan, M.U., Balsalobre- Lorente, D. (2020), Modelling coal rent, economic growth and CO2emissions: Does regulatory quality matter in BRICS economies? Science of the Total Environment, 710, 136284.
2. Apergis, N., Payne, J.E. (2012), Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. Energy Economics, 34, 733-738.
3. Bekun, F.V., Agboola, M.O. (2019), Electricity consumption andeconomic growth nexus: Evidence from Maki cointegration.Engineering Economics, 30(1), 14-23.
4. Bekun, F.V., Alola, A.A., Sarkodie, S.A. (2019), Toward a sustainableenvironment: Nexus between CO2 emissions, resource rent,renewable and nonrenewable energy in 16-EU countries. Science of the Total Environment, 657, 1023-1029.
5. Belaid, F., Youssef, M. (2017), Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria. Energy Policy, 102, 277-287.
6. Boontome, P., Therdyothin, A., Chontanawat, J. (2017), Investigating the causal relationship between non-renewable and renewable energy consumption, CO2 emissions and economic growth in Thailand.
7. Energy Procedia, 138, 925-930. Chen, Y., Wang, Z., Zhong, Z. (2019a), CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renewable Energy, 131, 208-216.

8. Chen, Y., Zhao, J., Lai, Z., Wang, Z., Xia, H. (2019b), Exploring the effects of economic growth, and renewable and non-renewable energy consumption on China's CO2 emissions: Evidence from a regional panel analysis. Renewable Energy, 140, 341-353.

9. Gyamfi, B.A., Bein, M.A., Bekun, F.V. (2020), Investigating the nexus between hydroelectricity energy, renewable energy, nonrenewable energy consumption on output: Evidence from E7 countries. Environmental Science and Pollution Research, 27(20), 25327-25339.

10. Inglesi-Lotz, R., Dogan, E. (2018), The role of renewable versus nonrenewable energy to the level of CO2 emissions a panel analysis of sub-Saharan Africa's Big 10 electricity generators. Renewable Energy, 123, 36-43.

11. Ito, K. (2017), CO2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. International Economics, 151, 1-6.

12. Khoshnevis Yazdi, S., Shakouri, B. (2017), Renewable energy, nonrenewable energy consumption, and economic growth. Energy Sources Part B, 12, 1038-1045.

13. Nguyen, K.H., Kakinaka, M. (2019), Renewable energy consumption,carbon emissions, and development stages: Some evidence from panel cointegration analysis. Renewable energy, 132, 1049-1057.

14. Ohlan, A., Ohlan, R. (2016), Generalizations of Fuzzy Information Measures. Switzerland: Springer International Publishing.

15. Ohlan, R. (2015), The impact of population density, energy consumption, economic growth and trade openness on CO2 emissions in India. Natural Hazards, 79, 1409-1428.

16. Ozturk, I. (2010), A literature survey on energy-growth nexus. Energy Policy, 38(1), 340-349.

17. Solarin, S.A., Bello, M.O., Bekun, F.V. (2021), Sustainable electricity generation: The possibility of substituting fossil fuels for hydropower and solar energy in Italy. International Journal of Sustainable Development and World Ecology, 28(5), 429-439.

18. World Bank. (2019), World Development Indicators. Available from: http://www.databank.worldbank.org/data/reports.aspx?source=worlddevelopmentindicators [Last accessed on 2023 Feb 02].