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Mitigating Emissions in India: Accounting for the Role of Real Income, Renewable Energy Consumption and Investment in Energy

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ABSTRACT

Accomplishing environmental sustainability has become a global initiative whilst addressing climate change and its effects. Thus, there is a necessity for innovation on part of economies as they seek energy for sustainable development. Thus, we explore the case of India a highly industrialized and heavy emitter of carbon emission. To this end, this study explores the effect of renewable energy, non-renewable, economic growth, and investment in the energy sector on CO_2 emission in the Indian economy. Canonical cointegration regression (CCR), fully modified least squares (FMOLS) and dynamic least squares (DOLS) were used to access the long-run elasticity of the variables as well as Granger causality analysis to detect the direction of causality relationship among the highlighted variables. Empirical regression shows a negative relation between CO_2 emission and renewable energy. Thus, suggesting that renewable energy serves as a panacea for sustainable development in the face of economic growth trajectory. However, there was a positive relationship between CO_2 emission and both non-renewable and real GDP growth. On the Granger analysis, we observe a one-way causality among renewable energy consumption and CO_2 emission, economic development, and energy investment. These outcomes have far-reaching policy direction of environmental sustainability target in Indian economy.

Keywords: Environmental Sustainability, Carbon Reduction, Renewable Energy, Fossil-fuel Energy
JEL Classifications: C32, C23, Q40, Q45

1. INTRODUCTION

Accomplishing environmental sustainability has become a global initiative whilst addressing climate change and its effects. On the other hand, non-renewable energy consumption has a driven production gain for many years (Adedoyin et al., 2020). However, the reduction of fossil-fuel sources and the problem of anthropogenic climate change has a wide emphasis on sustainable energy development. With the advent of technologies and the development of environmental conservation, clean energy choices are progressively important substitutes. However, clean energy solutions remain relatively underdeveloped in both developing and advanced markets, although they are increasingly call for a worldwide change to sustainable and low-carbon energy sources. This disposition is being resonated by the Intergovernmental Panel on Climate Change (IPCC) on topical studies on the climate-led urban development debate was how the transition from a nonrenewable source in the form of fossil fuel energy sources to sustainable energy (renewables) in the form of wind, photovoltaic and hydro energy would foster economic growth in emerging markets (Solarin et al., 2021). Nevertheless, the analysis of the impact of sustainable and non-renewable energy sources on economic growth renders insights on sustainable energy and inclusive growth strategies as posited by Apergis and Payne (2012).

Over the years, many studies have tried to identify the impact of renewable energy utilization, fossil fuel utilization, and sustainable development on environmental degradation. The bulk literature has not had a concerted agreement in the literature which this study seeks to bridge this gap. Belaid and Youssef (2017) explore the complex causal relationship involving CO_2, electricity generation use, fossil-based electricity consumption, and sustainable growth in Algeria through 1980-2012. autoregressive Global Lag Cointegration approach was utilized. Empirical findings support the presence of long-term linkages between parameters. They discover that, in the long term, income activity and non - sustainable electricity usage hurt the development of the climate, while the use of renewable energy has a useful impact on the climate. Additionally, Ito (2017) used panel data from 42 advanced states from the time frame of 2002-2011 to analyze scientifically the correlation connection CO_2 pollution, clean and non - renewable energy use as well as sustainable development. Their findings show that non-renewable energy used has a detrimental effect on sustainable development in developed nations. They notice that the use of green energy leads favorably to sustainable development in the future. Boontome et al. (2017) examined the causal involvement regarding fossil fuel, clean energy, emission, and sustainable development in Thailand from 1971 to 2013 utilizing the cointegration and causality methods. They identified the presents of cointegration involving the variables. From the causal involvement, it was observed that a one-way direction was identified involving fossil fuel and emission. Their studies exposed that; fossil fuel raises emission in Thailand. Additionally, Inglesi-Lotz and Dogan (2018) answered the discrepancies in the documentation by evaluating the factors (renewable and non-renewable capacity, income and trade openness) on CO_2 emission for the 10 largest oil producers in Sub-Saharan Africa for the duration 1980 to 2011 by utilizing rigorous cross-dependent panel approximation approaches. The long-term association among the factors was established. Rises in non-renewable energy usage boost emissions, although the reverse is true for sustainable energy. As respects to the orientation of the causal interaction, they noted the unidirectional causality of pollution, employment, trade, and non - renewable energy to sustainable sources of energy.

More recently, Bekun et al. (2019) used structured panel evidence from the 1996-2014 entire cycle for chosen EU-16 members. The Kao test demonstrates the co-integration of greenhouse gas emissions, productivity growth, renting of oil and gas, sustainable energy, and non-renewable energy use. The Panel Pooled Mean Group-Autoregressive Autoregressive Distributive Lag Model (PMG-ARDL) indicates a strong, long-term correlation between the country's natural resource rent and Carbon dioxide emissions. Insinuating that overreliance on the rent of natural resources impacts the protection of the environment of panel states as preservation and maintenance choices are overlooked. Their research shows that non-renewable energy use and business output boost greenhouse gas emissions, while sustainable energy use decreases Carbon dioxide emissions[1].

1 For brevity's sake more literature on the Growth-energy growth nexus see Ozturk (2010)

Furthermore, Chen et al. (2019a) analyzed the connection regarding per capita carbon dioxide (CO_2) emissions, gross domestic product (GDP), sustainable energy, non - renewable, output, and foreign trade for China from the span 1980-2014. They concluded that there was a long-term association between these factors. A further interesting aspect was that China has no Environmental Kuznets Curve (EKC) among output and carbon emission. Their long-term forecasts indicate that fossil fuel and GDP increase pollution, while clean energy and international exchange hurt Carbon emission. Short-term Granger causality analysis shows a bi-directional causality from international trade, CO_2 emissions, and fossil fuel to clean energy. The result shows that green energy use is a crucial approach to rising CO_2 pollution across the period.

Furthermore, the goal of this study is to examine the effects of clean energy as well as fossil-fuel-based energy usage on environmental sustainability targets in India by adding investments in energy in the empirical framework of this present study. This study is built on a carbon-income function. The additional variables incorporated help this study underscores the determinant of carbon emission for the case of India. The incorporation of additional variables aid in circumventing for omitted variable bias in the econometrics modeling. The choice of India is motivated by first, been one of the major growing energy-dependent states in the world. Second, India's balance of energy is largely controlled by global fossil fuel sources. Nevertheless, India's per capita usage of clean energy is much below that of most emerging countries (Ohlan, 2015, Ohlan and Ohlan, 2016). The same is expected to rise significantly in the foreseeable period, through the quest for a better superiority of life as well as the capacity for exponential growth of the industrial segment in current policies (i.e., Build Asia, National Industrial Zones, Technological Asia, and Venture India). Growth of energy production in the area, and on the other hand, is unlikely to continue with intensified competitiveness. As a consequence, the state's reliance on importing resources is predicted to rise even additional in the coming years. Any loss of fossil fuel supplies due to an unpredictable geographical condition could lead to extreme energy shortages, which could, as a result, hinder India's socio-economic growth. it is on this premise this study leverages on FMOLS, DOLS, and Canonical Cointegrating Regression (CCR) for the Indian clean energy and fossil fuel usage economic growth by exploring the long-term elasticity and causality relationship between the highlighted variables.

The remainder of this study is structured as: Section 2 offers the data and method employed While section 3 renders the discussion of empirical results. Section 4 concludes the study with policy direction.

2. METHODOLOGY

This current study explores the effect of both clean and non-renewable energy usage on CO_2 emission for the case of India. To do this, data from the World Bank indicators were used. Pollutant in the form of CO_2 emission is used for environmental degradation while GDP growth in (2010 US) has been used as a measure for economic growth and investment in the energy sector (Investment in energy with private involvement (current US$) and growth of the economy (GDP per capita (constant 2010 US$). The study data spans from 1990 to 2016 which is determined by the accessibility of data.

2.1. Formulation of Model

To explore the effect of sustainable energy usage and non-renewable energy consumption on CO_2 emission in a carbon-income function, the follow model is fitted as:

$$CO_{2t}=f\,(REC_t, NREC_t, GDP_t, IEC_t) \quad \text{(i)}$$

here CO_2 presents carbon dioxide emissions in metric kg per, GDP growth, REC represents renewable energy consumption (% of total final energy consumption), NEC denotes fossil fuel energy consumption (% of total), GDP= GDP per capita (constant 2010 US$) and IEC= Investment in energy with private participation (current US$). There exist few studies in the extant literature on the relationship between energy consumption and emissions level (see Khoshnevis Yazdi and Shakouri, 2017; Nguyen and Kakinaka, 2019), the current study focuses on the Indian economy to explore the determinants of CO_2 emissions. More specifically this study incorporates investments in the energy sector to substitute trade transparency and urbanization which distinguishes it from the studies of (Khoshnevis Yazdi and Shakouri, 2017).

Utilizing the double log-linear modification of the Eq variables. (1) The econometric definition of the time series is specified as:

$$LnCO_{2t}=\beta_0+\beta_1 LnREC_t+\beta_2 LnNREC_t+\beta_3 LnGDP_t+\beta_4 LnIEC_t+\mu_t \quad \text{(ii)}$$

Where Ln denotes logarithm transformation of betas to achieve elasticity of the outlined variables.

3. EMPIRICAL RESULTS AND DISCUSSION

This section discusses and describes all empirical findings in a stylized manner. Table 1 demonstrates that the CO_2 has the maximum level over the span undergoing study. Both sequences show negative skews apart from emissions and GDP, while Pearson's pairwise correlation reveals that CO_2 emission are closely related to economic development and other macroeconomic variables under consideration

For stationarity purposes, the Dickey and Fuller (ADF) (Dicker and Fuller, 1981) was utilized to check the stationarity structure among the factors used in this analysis. The cointegration technique was implemented to determine the long-term equilibrium relationship between the variables in the Eqs. (2). Johansen cointegration test equilibrium (cointegration) is used to determine the cointegration properties. While the FMOLS, DOLS, and CCR were used to verify the long-term elasticity of the variables. Subsequently, Granger Causality analysis was utilized to verify the causal interaction of the variables.

Table 2 presents the stationarity test. The stationarity test is necessary to ascertain the integration properties of variables under review. This is pertinent to avoid working with variables integrated of order 2. As such variables will translate into spurious regression and by extension misleading inferences (Bekun and Agboola, 2019). From Table 2 we confirm that our study variables are integrated of order 1. i.e., after first differencing. Subsequently, we proceed to explore the equilibrium properties of the series as seen in Table 3.

The Johansen cointegration test shows that the null hypothesis of no cointegration was rejected. Thus indicating 2 cointegration

Table 1: Descriptive statistics and correlation Metrix analysis

	$LnCO_2$	LnGDP	LnIEC	LnNREC	LnREC
Mean	0.1069	6.9287	21.329	4.1851	3.8366
Median	0.0911	6.8868	21.217	4.1833	3.90648
Maximum	0.2562	7.6500	24.263	4.3437	4.0716
Minimum	–0.0508	6.3552	16.410	3.9846	3.5309
Std. Dev.	0.0992	0.4022	1.6030	0.1027	0.1761
Skewness	0.1118	0.2063	–0.5598	–0.2381	–0.3881
Kurtosis	1.63464	1.8250	4.5433	2.0685	1.6618
	$LnCO_2$	**LnGDP**	**LnIEC**	**LnNREC**	**LnREC**
Correlation analysis					
$LNCO_2$	1				
LNGDP	–0.9123***	1			
LNIEC	–0.494***	0.542***	1		
LNNREC	–0.886***	0.982***	0.594***	1	
LNREC	0.841***	–0.985***	–0.547***	–0.964***	1

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

Table 2: Unit root test

Statistics (Level)	LnCO2	LnGDP	LnREC	LnNREC	LnIEC
$\pi\tau$	–0.4474	2.8418	1.1731	–2.0601	–2.5154
$\pi\vartheta$	–2.7396	–2.4748	–1.8322	–2.8044	–2.9580
Statistics (1st difference)	**LnCO2**	**LnGDP**	**LnREC**	**LnNREC**	**LnIEC**
$\pi\tau$	–5.7643***	–4.8977***	–3.3439**	–4.9050***	–8.0448***
$\pi\vartheta$	–5.6246***	–5.4344***	–3.5334*	–5.1156***	–7.9385***

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

Table 3: Johansen test to cointegration

Hypothesis no. of CE (s)	Fisher stat (from trace)	Eigenvalue	P-value
r ≤ 0	97.982***	0.827203	(0.0001)
r ≤ 1	50.580**	0.641350	(0.0271)
r ≤ 2	22.894	0.358380	(0.2513)
r ≤ 3	10.913	0.205607	(0.2169)
r ≤ 4	4.6982	0.159710	(0.3302)

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

Table 4: CCR, DOLS and FMOLS

Variables	CCR	DOLS	FMOLS
LnGDP	–0.9119***	–0.9400***	–0.9478***
P-value	(0.0000)	(0.0009)	(0.0000)
LnREC	–1.2397***	–1.1447***	–1.2518***
P-value	(0.0000)	(0.0037)	(0.0000)
LnNREC	0.7097***	1.0838**	0.8366***
P-value	(0.0017)	(0.0282)	(0.0054)
LnIEC	–0.0081**	–0.0024	–0.0081**
P-value	(0.0432)	(0.8224)	(0.0142)
Constant	8.3856***	6.5367**	8.1495***
P-value	(0.0000)	(0.0127)	(0.0000)
R-SQUARE	0.957	0.9836	0.9567
ADJ R-SQUARE	0.949	0.9545	0.9492

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

vectors. Thus, suggesting cointegration among the variables over the sampled period.

This study applied a battery of regression techniques namely, the canonical cointegrating regression (CCR), fully modified least squares (FMOLS) and dynamic least squares (DOLS) were employed to access the long-run elasticity of the variable which is presented in Table 4 above. Form the estimation it was verified that; renewable energy consumption was 1% negatively significant in all the three estimations. Thus, a 1% increase in renewable energy consumption will decrease emissions by 1.24%, 1.15% and 1.25% respectively. Furthermore, all the three-estimation showed a positive significant for non-renewable energy consumption. Thus, a 1% increase in the utilization of non-renewable energy will increase emission of 0.71%, 1.08% and 0.84% respectively. Moreover, the estimations indicated that GDP had 1% negatively significant level with emissions. Thus, 1% increase in GDP will decrease emission by 0.91%, 0.94% and 0.95% respectively in the long run and all the estimation affirms the findings of Bekun et al. (2019). Lastly, there was a 5% negatively significant at CCR and FMOLS in respect to investment in the energy sector. Thus, a 1% increase in investment in the energy sector will decrease emission by 0.0081% in CCR and 0.0082% in FMOLS. From the table above, the estimations show that all the variables affect emission both in positive or negative in the long run. After confirming the long-run elasticity of the variables, there was a need to check the causality association of the variables by employing the Granger Causality analysis.

The analysis of Granger causality reported in Table 5 shows that a - one-way directional causality was identified between renewable energy utilization and emission, sustainability development and investment in the energy sector, and sustainable development and renewable energy utilization. These outcome resonates with the

Table 5: Granger causality analysis

Null hypothesis	F-Statistics	P-value
LNGDP≠$LNCO_2$	1.566	(0.2312)
$LNCO_2$≠LNGDP	0.004	(0.9953)
LNIEC≠$LNCO_2$	0.140	(0.8699)
$LNCO_2$≠LNIEC	0.722	(0.4967)
LNNREC≠$LNCO_2$	2.421	(0.1121)
$LNCO_2$≠LNNREC	1.192	(0.3223)
LNREC≠$LNCO_2$	1.003	(0.3829)
$LNCO_2$≠LNREC	3.401*	(0.0516)
LNIEC≠LNGDP	1.226	(0.3126)
LNGDP≠LNIEC	4.389**	(0.0249)
LNREC≠LNGDP	0.296	(0.7460)
LNREC≠LNGDP	2.403	(0.1138)
LNGDP≠LNREC	0.247	(0.7831)
LNGDP≠LNREC	2.715*	(0.0883)
LNNREC≠LNIEC	0.490	(0.6186)
LNIEC≠LNNREC	0.015	(0.9843)
LNREC≠LNIEC	1.042	(0.3693)
LNIEC≠LNREC	0.648	(0.5326)
LNREC≠LNNREC	1.199	(0.3203)
LNNREC≠LNREC	0.842	(0.4440)

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

finding of Gyamfi et al. (2020) and also give credence to the need for energy diversification to cleaner energy technologies to foster sustainable development targets.

4. CONCLUDING REMARKS

The purpose of this study is to examine how the Indian economy emission is affected by renewable energy consumption, non-renewable energy consumption alongside economic growth and investment in the energy sector between 1990 and 2016. Our study data were sourced from the World Bank indicators database. India is among the emerging 7 nations (E7) which means the nation's attention is shifting to industrialization with a lot of human activities which will result in producing more emission which stems from anthropogenic activities which in turn affect the environment in the long run. The majority of nations have therefore adopted initiatives and innovation into mitigating the reduction of emission by strict adherence to the Kyoto procedure whereby India is not exempted from these strides for a cleaner and more habitable ecosystem. To this end, this study employed the canonical cointegrating regression (CCR), Fully modified least squares (FMOLS), and dynamic least squares (DOLS) to access the long-run elasticity of the variable as well as the Granger Causality analysis to identify the causality relationship of the variables.

The regression from CCR, DOLS and FMOLS are in harmony that renewable energy significantly decreases emission by 1.24%, 1.15% and 1.25% respectively, non-renewable energy consumption increases emission by 0.71%, 1.08%, and 0.84% respectively and GDP decreases emission by 0.91%, 0.94% and 0.95% respectively. All these three variables that is renewable energy, non-renewable energy and GDP estimations are in confirmations to the study of Bekun et al. (2019). Moreover, investment in financial development had a 0.0081% in CCR and 0.0082% in FMOLS decreasing impact on emission in the long run. Nevertheless, Granger Causality test shows a unidirectional causality among renewable energy consumption and emission, sustainability development and investment in energy sector and sustainability development and renewable energy consumption.

Given the above-highlighted results, from a policy standpoint, Indian economy needs to adopt measures such as incentives for carbon reduction, tax advantages, and financial aid to businesses manufacturing such infrastructures for renewable energy. Furthermore, there is a need for a paradigm shift from the traditional energy consumption mix which is based on fossil-fuel to renewables. Renewables have been outlined as more environmentally friendly to environmental sustainability targets as well as investment in energy from public-private partnerships in the energy sector. This traction will translate into a green environment and economic growth.

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