International Information and Engineering Technology Association
Advancing the World of Information and Engineering

International Journal of Environmental Impacts
Vol. 6, No. 2, June, 2023, pp. 57-64
Journal homepage: http://iieta.org/journals/ijei

An Econometric Analysis of India's Urbanization, Energy Consumption, Economic Growth and CO_2 Emission

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https://doi.org/10.18280/ijei.060201

Received: 6 February 2023
Revised: 21 April 2023
Accepted: 5 May 2023
Available online: 30 June 2023

Keywords:
environment, energy consumption, economic growth, CO_2 emissions, VECM, urbanization

ABSTRACT

This study endeavors to elucidate the intricate relationships and impacts of energy consumption, urbanization, and economic growth on carbon dioxide (CO_2) emissions in India, spanning from 1975 through 2019. Data for this analysis is procured from the World Bank. An application of the Vector Error Correction Model (VECM) tests the long-term relationships between these variables. Additional verification of causality is sought through the Granger causality test. The study reveals unidirectional causalities: energy consumption and economic growth both lead to increased CO_2 emissions. In the short run, our findings indicate a causality flow from Gross Domestic Product (GDP) and energy consumption to CO_2 emissions, while urbanization does not significantly contribute to this causality. The results of the VECM, Granger causality, and Wald tests corroborate the existence of a long-term causal relationship between energy consumption, urbanization, and economic growth on CO_2 emissions in India. Based on these findings, the study proposes that India should focus on the introduction and rejuvenation of energy resources that can address the country's escalating energy demand. A shift from conventional energy sources including coal, hydro, oil, and gas to renewable, environmentally-friendly alternatives is recommended. This transition would contribute to a reduction in CO_2 emissions, thus promoting sustainable economic growth for India in the long run.

1. INTRODUCTION

With the fast-paced improvement in technology, resulting in exponential economic growth, there has been a dramatic rise in carbon dioxide emissions across the globe. The rise in industrialisation and consumerism has resulted in industrial pollutants negatively affecting the environment. Degrading the environment has become a serious issue, especially in developing nations with limited resources. Economic growth and development are inextricably related to the use of fossil fuels and changes in land use.

Three factors, energy, CO_2 emission and urbanisation, are major contributors to carbon emission.

Energy- is an important part of any country's economic growth and human development. India is the world's second-largest coal-producing nation. 55% of the country's overall energy supply is met by coal. It is one of India's most important sources for meeting its domestic energy demand. Also, it is one of the country's major contributors to carbon emissions. There are few studies on India's energy consumption's impact on environmental degradation. Over the past decades, many researchers have analysed the causal relationship between energy consumption and CO_2 emissions and various studies have investigated the relationship between CO_2 emissions and per capita GDP, Urbanization, and energy consumption. Shahbaz et al. [1] investigated cointegration using the ARDL bounds testing method, applying econometric methods and incorporating structural breaks. According to the findings, foreign direct investment, trade transparency, and carbon emissions reduce energy demand. The development of the economy and the use of renewable energy positively impact energy usage.

Urbanisation- In less developed countries, job opportunities and prosperity, among other factors, attract people to cities. Half of the world's population already lives in cities. It is anticipated that by 2050 two-thirds of the world's population will reside in urban areas, subsequentially increasing environmental degradation. Parshall et al. [2] established a relationship between energy consumption and CO_2 emissions at the urban scale. He used spatial analysis to discover that urbanisation is one of the major influences on energy use in the United States. Madlener and Sunak [3] examined how urbanisation affects urban systems and energy demand. According to their findings, urbanisation is a significant driver of economic growth and increases energy demand. Lu and Huang [4] also investigated the impact of urbanisation on CO_2 emissions in China between 1980 and 2009. There is more to be analysed in the correlation between environmental issues and regional growth, especially including urbanisation as an important factor. Hossain [5], Sharma [6], Kasman and Duman [7] examine the relationships between gas emissions, energy consumption, real production, trade, and urbanization for newly industrialised nations between 1971 and 2007.

Economic Growth- India is the world's largest country by population and 5th largest economy by GDP. India is the third largest emitter of greenhouse gases (GHG) after China and the United States. Due to rising CO_2 emissions, India has seen an increase in extreme weather events. There have been unprecedented hot spells, a shift in monsoons bringing droughts and floods, and a major drop in crop yield, all potentially destabilising the country's social and economic system. Since agriculture in India is primarily rain-dependent, higher or lower-than-average rains strongly impact the country's economy.

We have selected energy, economic development and urbanisation as factors affecting carbon emission. However, although there can be other variables affecting carbon emission, our study's scope is limited to these variables. There are a few articles in which researchers attempted to determine the relationship between energy use and CO_2 emissions and economic growth and CO_2 emission in India. There are many factors that contribute to environmental degradation, but we chose three important factors that play a significant role in environmental degradation. We chose urbanisation as the third main reason since India's metropolitan cities are the most polluted in the world. According to the current State of Global Air study on air quality and health in cities, New Delhi, Kolkata, and Mumbai are among the top 20 most polluted cities in the world in terms of PM2.5 levels.

India has pledged to reduce its emissions by 45% by 2030, as declared by it in COP26 in 2021, using Nationally Determined Contributions (NDC). India has also planned to achieve net zero emissions by 2070 [8].

This study is a timely effort to address the vacuum in the literature on India's energy and growth and its environmental impact. Even since India is the second largest populated country in the world, the present research is an effort to understand how India can play an important role in making environmental policy and impacting the world.

2. LITERATURE REVIEW

Researchers and policymakers in developing and developed countries have long debated environmental quality and its determinants. The environmental Kuznets curve (EKC) hypothesis sparked this debate. According to Grossman et al. [9, 10], the EKC hypothesis demonstrates an inverted U-shaped relationship between environmental degradation and per capita income. This implies that emissions rise during the early stages of economic development. However, once a country achieves a certain level of prosperity, emission levels begin to fall. However, the empirical evidence is inconclusive. These research' major environmental contamination markers are SO2 and CO_2. In the EKC literature, vector energy use is frequently employed as a factor of environmental contamination. Oil use, pollution of the atmosphere, and economic growth are all linked. Energy consumption is a fundamental component of industrial development and economic progress in all countries.

Several research has been carried out to see if there is a correlation between energy use, urbanisation, GDP growth, and environmental damage in different countries and locations. An energy indicator that forecasts CO_2 emissions is used to evaluate the EKC in empirical studies of energy economics. In terms of specific regions, we can look to works like Apergis and Payne [11] for Central America, Zhang and Cheng [12] for China, Wang et al. [13] for China, Halicioglu [14] for Turkey, Ozturk and Acaravci [15] for Turkey, Pao and Tsai [16] for Brazil, Alam et al. [17] for Bangladesh, and Kasman and Duman [7] for new E.U. member and candidate countries. As an added bonus, research involving several MENA nations has factored in how much power each uses. Several studies have employed simultaneous equations models to examine the connection between carbon dioxide (CO_2) emissions, energy consumption, and economic growth. These include Farhani and Shahbaz [18] and Arouri et al. [19] and Omri [20]. This and other studies show that cutting energy waste helps lower greenhouse gas emissions. Using the ARDL limits test and the VECM Granger causality technique, Acaravci and Ozturk [10] investigate the links between energy use, GDP growth, and carbon dioxide emissions across 19 European countries. Using energy efficiently reduces carbon dioxide emissions and benefits Denmark, Germany, Greece, Italy, and Portugal, as shown by the data. In Denmark and Italy, GDP growth correlates with lower CO_2 emissions. Using the panel FMOLS method, Saboori et al. [21] analysed the correlations between OECD countries' energy consumption, CO_2 emissions, and GDP growth from 1971 to 2009. There appears to be a positive, long-term association between economic expansion and CO_2 emissions. The team also uncovered a positive, long-term, and bidirectional relationship between energy consumption and CO_2 emissions. Between 1990 and 2010, the BRICS countries' energy use, economic growth, and CO_2 emissions were studied by Cowan et al. [22]. This was achieved through the use of panel causality tests. In South Africa, a Granger causality is established between GDP growth and carbon dioxide emissions, and there is a Granger causality between CO_2 emissions and economic growth in Brazil.

Furthermore, India has discovered Granger causation between power consumption and CO_2 emissions. To explain the relationship between urbanization and the natural environment, a number of hypotheses have been suggested. Sehrawat et al. [23] discovered that the usage of fossil fuels such as coal, oil, and gas cause the majority of CO_2 emissions. Wages, population, international trade, energy use, and urbanization all impact a country's CO_2 emissions. According to the research, financial development is expected to increase carbon emissions since adequate and solid financial intermediation makes the loan process more convenient. As a result, buyers buy large items like houses, cars, air conditioners, and refrigerators, all of which emit more CO_2. Financial growth lowers transaction costs, which widens credit sources, lowers operational risk when purchasing new equipment, and subsequently lowers capital spending on new projects, reducing carbon emissions. Financial advancement can entice foreign direct investment (FDI), and extensive research and development (R&D) enhances economic expansion, and, as a result, carbon emissions will increase. Financial expansion may result in more industrial activity, which may result in increased emissions. The connection between carbon dioxide emissions, energy consumption, financial development, and economic growth in India has received scant attention despite its importance.

Urbanisation changes may affect economic development, energy use, and CO_2 emissions. Urbanisation has both a positive and negative effect on CO_2 emissions. If urbanization has a positive and statistically significant effect on environmental deprivation, forecasting models and climate change, the policy could be affected. Urbanisation is a new variable that has started to be included in the straightforward model. Martnez-Zarzoso and Maruotti [24] address the possible impact of urbanisation on environmental degradation through a number of approaches. An easy way to look at it is that more people living in cities means more people using cars, making more things, and releasing more greenhouse gases. Incorporating commerce and urbanisation into the basic EKC model, Hossain et al. [5-7] provide a more comprehensive framework. Despite the lack of a long-term causal relationship, they find evidence of short-term unidirectional causality in the relationships between the variables were examined: from real output and trade openness to carbon dioxide emissions, from real output to energy consumption, from GDP to trade openness, and from trade openness to urbanization.

From 1985 to 2005, Sharma [6] analysed 69 nations to determine the correlations between environmental quality, energy consumption, GDP, openness, and Urbanization. The statistics show that urbanisation helps lower CO_2 levels while increasing trade openness, per capita output and energy usage all contribute to environmental degradation. Specifically, between 1992 and 2010, Kasman and Duman [7] focused on new members and candidate nations of the European Union, examining the correlations between greenhouse gas emissions, energy consumption, actual production, trade, and urbanization. The EKC hypothesis is further supported by the findings of the fully modified ordinary least squares (FMOLS) regression, which shows that openness and urbanisation have a beneficial effect on gas emissions. In addition, CO_2, GDP, energy use, trade liberalisation, and urbanization have unidirectional causal relationships, as do trade liberalisation, energy use, and urbanization. The potential influence of urbanisation on environmental degradation is discussed in several ways by Martinez-Zarzoso and Maruotti [24]. Basic logic suggests that as urban populations grow, so do energy demand for transportation, for manufacturing, and for emissions of greenhouse gases. Adding to commerce and urbanisation, Hossain et al. [5-7] develop the basic EKC model further. When urbanization is considered part of the environmental function, there is much to discuss regarding environmental concerns and regional expansion. Between 1992 and 2010, Kasman and Duman [7] focused on new members and member nations of the European Union, and they examined the correlations between greenhouse gas emissions, energy consumption, actual production, trade, and urbanization. The EKC hypothesis is further supported by the fully modified ordinary least squares (FMOLS) regression findings, which show that trade openness and urbanisation have a beneficial effect on gas emissions. In addition, CO_2, GDP, energy use, trade liberalisation, and urbanization have unidirectional causal relationships, as do trade liberalisation, energy use, and urbanization.

Energy and environmental policies that fail to report the effect of urbanization and economic development on carbon emissions are likely to yield inaccurate findings, making progress toward sustainable development targets more challenging. Therefore, it is important to analyse the relationship between carbon emission and its relationship with energy, urbanization and economic growth. Sadorsky [25] analyses three theories concerning the link between urbanization and its environmental impact. The theory of ecological modernisation, urban environmental change, and compact cities are all well-known concepts. According to ecological modernisation theory, urbanisation is a vital social transformation process. Economic growth becomes the major goal when cultures go from low to moderate development, and environmental difficulties may occur. Environmental contamination becomes more severe as development advances. The urban environmental transformation theory investigates the relationship between environmental challenges and local urbanisation. This idea holds that cities often get wealthier due to industrial manufacturing. This can also lead to industrial collapse. However, regulations meant to protect the environment and technological advances can help curb industrial pollution. The advantages of urbanization are outlined in the compact city hypothesis. Economies of scale for public services may result from increased urbanisation, leading to reduced pollution levels. These hypotheses suggest that urbanization can have both beneficial and detrimental environmental results. The connection between urbanisation, energy consumption, and CO_2 emissions has been the topic of much empirical study.

Urbanisation leads to higher CO_2 emissions in cities, regardless of income level, as demonstrated by the panel regression results. Modelling the connection between energy use and carbon dioxide emissions at the city scale is the focus of work by Parshall et al. [26]. Madlener and Sunak [27] study how urbanisation affects urban systems and energy demand in emerging countries. The data suggest that urbanisation contributes to economic growth and increases energy demand. Between 1980 and 2009, The effects of urbanisation on China's CO_2 emissions are studied by Lu and Huang [4]. The Granger causality test suggests that urbanisation contributes to releasing greenhouse gases.

Long-term Granger causation between urbanisation and CO_2 emissions is supported by the results of a Granger causality test conducted with VECM. There is no link between the variables in the short term. Hossain [28] investigates the potential causal relationships between energy consumption and economic growth using the ARDL limitations research approach. He applied the VECM Granger causality test to find the relationship among international exchange, urbanization, and CO_2 emissions from 1960 to 2009. The variables are discovered to have a connection. Long-term data also shows a correlation between energy use and CO_2 production. The results demonstrate a long-term, bidirectional causal relationship between energy consumption and CO_2 emissions. The results also point to a Granger causal relationship between urbanisation and CO_2 emissions in the long run.

To determine how urbanization affected developing countries' CO_2 emissions from 1975 to 2003, Martínez-Zarzoso and Maruotti [24] looked at a wide range of data. As part of this study, we use a refined variant of the STIRPAT model. According to the data, urbanisation and CO_2 emissions appear to be related in a way that resembles an upside-down U. Poumanyvong et al. [29] utilise the STIRPAT model to analyse the effect of urbanisation on transportation energy consumption in developing, developed, and high-income countries from 1975 to 2005. According to the data, urbanization reduces road energy use. However, the extent of the effect varies depending on the income group.

Çetin and Ecevit [30] studied how urbanisation affects energy use and carbon dioxide emissions in MENA countries. The study found that energy consumption and CO_2 emissions were affected differently by urbanization in oil-exporting countries compared to those that did not produce oil.

Consuming energy was found to correlate positively with CO_2 emission. Using panel regression methods, Sadorsky [31] looked into how urbanisation affects CO_2 emissions in developing countries. Both the energy intensity and wealth coefficients are positively and statistically significant. Statistically speaking, urbanization has a positive effect, but it is almost insignificant. Wang et al. [13] used panel data models to analyse the dynamics between urbanisation, energy consumption, and CO_2 emissions in 30 Chinese provinces between 1995 and 2011.

The relationship between or among nations in terms of economic and commercial activities has heightened academic interest in the pollution haven theory. As soon as was practicable, the theoretical groundwork for studying how economic variables affect carbon intensity was constructed, including examples such as in the study [9]. According to in the study of Alpay [32], differences in carbon emissions levels across countries can be attributed to a number of economic factors, including but not limited to growth rates, competitive advantages, resource intensity traded, current levels of environmental awareness, and the presence of environmentally friendly policies. With Autoregressive Distributed Lag (ARDL) and Johansen cointegration methods, Naranpanawa [33] looked at the long-term connection between business and ecology. This study concluded that the connection between commercial activity and carbon emissions is weak and short-lived. Keho [34] used the ARDL panel to investigate the long-term consequences of trade on the environment and found that, between 1970 and 2010, trade was a major contributor to environmental degradation in 11 Economic Community of West African States (ECOWAS) countries. Between 1972 and 2011, Rahman and Kashem [35] studied the connections between carbon pollution, energy consumption, and industrialisation in Bangladesh using ARDL bounds testing and the Granger causality introduced by Toda and Yamamoto in 1995. The authors discovered that the model demonstrates long-run co-movement and that the variables remain causally connected. They also show a positive relationship between carbon intensity and economic growth throughout the time period under consideration. Twelve countries in Sub-Saharan Africa were studied to determine the long-term and causative relationship between energy consumption, CO_2 emissions, and economic growth using cointegration limits testing and Granger causality Esso and Keho [36] from 1971 to 2010. The findings of observational research differ between economies. Sulaiman [37] applied the Granger causality method developed by Toda and Yamamoto to examine the correlations between Nigeria's rising GDP, the country's carbon CO_2 emissions, and energy consumption (1995). According to the numbers, there is a unidirectional link between energy use and carbon output and a similar one between carbon output and economic growth. The author found a causal link between rising energy use and expanding economies. To look for long-term correlations and analyse the causes among variables in Nigeria from 1970 to 2009, Nnaji et al. [38] used limit testing ARDL to check for cointegration and granger causality. The researchers found that CO_2 emissions are linked to international trade and that this relationship works both ways. Prior research by Chuku and Ndifreke [39], employing a similar methodology, found that trade has no impact on CO_2 emissions in Nigeria. The researchers found that affluence increases are linked to more pollution. Appiah-Konadu [40] found that trade liberalisation had a negative impact on CO_2 emissions in Ghana using a least-squares multiple regression analysis of the environmental effects of trade openness from 1970 to 2010. Between 1995 and 2016, Balsalobre-Lorente et al. [41] analysed data from 16 OECD countries to determine whether economic growth and carbon pollution correlated. They did this using the EKC theory proposed by environmental psychologist Simon Kuznets. The study found that environmental sustainability deteriorated when economies attempted to correct institutional inequities. By showing that widespread economic growth, the use of renewable electricity, and innovation reduced environmental pollution in 17 OECD nations from 1990 to 2012, they lent credence to the EKC theory. Using data from 1970 to 2010, Michieka and Fletcher [42] analysed China's exports, CO_2 emissions, coal use, and trade openness in 2012. The preliminary results show a Granger causal relationship between exports and emissions and between exports and coal use. GDP influences future CO_2 volatility. More importantly, it indicates that trade is considered a major contributor to rising CO_2 emissions. Shakeel [43] examined the relationship between energy, GDP, and export. He discovered that 43.7% of research provided evidence supporting the growth hypothesis, 50% of studies provided evidence supporting the feedback hypothesis, and 6% of these total studies provided data supporting the neutrality hypothesis. Zeshan et al. [44-46] built a multi-sector and multi-region energy augmented recursively dynamic computable general equilibrium water model to assess the effectiveness of climate change mitigation and adaptation programmes in South Asian countries, as well as other studies on related economic concerns numbers [47].

3. MATERIALS AND METHODS

The study's main objective is to discover the relationship between urbanisation, energy consumption, economic growth and CO_2 emissions and investigate the impact of urbanization, energy consumption and economic growth on CO_2 emissions.

Two models were used to analyse the connection between urbanisation, energy use, economic growth, and carbon dioxide emissions. First, Augmented Dickey-Fuller (1979) was applied to verify the stationarity of the data series. Second, Johansen's Cointegration and Vector Error Correction Model (VECM) were used to examine the lead-lag relationship between CO_2 emissions (metric tons per capita), GDP per capita (current US$), Energy Consumption (kWh per capita), Urban Population (% of Total). Further, the necessary lag length of the data series was selected on the basis lag selection criteria. The VAR model is used to measure long-run causality.

Additionally, the Wald test is used to measure short-run causality. The data analysed is retrieved from 1971 to 2019 from the World Bank website. Data was deemed sufficient and in line with previous studies to conduct research.

The unit root test will be used in the first phase to investigate the stationarity of the variables. The Phillip Perron test and the ADF test were employed to test the stationarity of variables. If the variables are stationary at the first difference, the Johansen-cointegration test will be employed to investigate the long-run bidirectional link between urbanisation, energy consumption, GDP and CO_2 emissions. If the models are cointegrated, the Granger causality-based model, the vector error correction model (VECM) and the Wald test will be utilised to investigate the variable's short and long-term bi-directional causal linkages. The VECM model is free from serial correlation and heteroskedastic and is the best fit for conducting research.

The Johansen cointegration model and the vector error correction model were used in this paper to examine the long-term equilibrium and short-term dynamic relationship between carbon emissions, energy, economic growth, and urbanisation in India. We can use the vector error correction model if the variables are cointegrated. The VECM model is commonly used for long and short-run equilibrium. The causal link between CO_2 emissions, energy use, GDP development, and urbanisation is expressed in the following equation.

$$\Delta LCO2_t = \varphi + \sum_{i=1}^{n} \alpha_i \, \Delta LCO2_{t-i} + \sum_{j=1}^{n} \beta_j \, \Delta LGDP_{t-j} + \sum_{k=1}^{n} \gamma_{4k} \, \Delta LUP_{t-k} + \sum_{q=1}^{n} \delta_q \, \Delta LEC_{t-q} + \xi \quad ECT_{t-1} + \mu_t \tag{1}$$

where, LCO2 is the average amount of greenhouse gas emitted per person, LEC is the average amount of energy used per person, and LGDP is the average amount of real GDP per person. LUP is the urban population (Percentage of Total), and ϕ, α, β, γ, and δ are coefficients of the polynomial; n is the optimal lag; ECT_{t-1} is the correction term. The above equation expresses the causality test model from LGDP, LEC and LUP to LCO2. If the null hypothesis (H0: $\beta_j=\gamma_k=\delta_q=0$) is rejected in equation (1), there is a short-term Granger causality from LEN, LGDP and LUN to LCO2. The coefficient ξ of the error correction term shows the speed of adjustment towards equilibrium. If the null hypothesis (H0: $\xi=0$) is rejected, long-term Granger causality flows from LEN, LGDP and LUN to LCO2.

4. RESULTS AND DISCUSSION

The descriptive statistics of CO_2 emissions, GDP per capita, Energy Consumption, and Urban Population are shown in Table 1.

Table 1. Descriptive statistics of CO_2 emissions, GDP per capita, Energy Consumption, and Urban Population

	Mean	Median	Std. Deviation	Skewness
LCO2	0.038024	0.039031	0.031439	1.166796
LUP	-0.000135	-3.01E-05	0.000872	-1.634373
LEC	0.049099	0.049002	0.026896	-0.213493
LGDP	0.062469	0.060424	0.080905	-0.376057

Source: Authors' Compilation

As a preliminary investigation, Augmented Dickey-Fuller (ADF) and Philip-Perron (PP) tests were employed to test the stationarity of CO_2 emissions, GDP per capita, Energy Consumption, and Urban Population, and its results are presented in Table 2.

The Table 2 reveals that all the data series on CO_2 emissions, GDP per capita, Energy Consumption, and Urban Population are stationary after the second difference.

Table 2. Unit root test

	ADF		PP	
	Level	Second Difference	Level	Second Difference
LCO2	2.651438(1)	-4.99418 (0.0002)	2.640187 (1)	-5.04837 (0.0002)
LUP	0.727405 (0.9912)	-4.05179 (0.0003)	-0.30409 (0.9153)	-4.00045 (0.0003)
LEC	2.69938 (1)	-8.49574 (0.00)	4.072657 (1)	-9.21886 (0.00)
LGDP	4.296923 (1)	-10.5942 (0.00)	5.59181 (1)	-4.70191 (0.0005)

Source: Authors' Compilation

Table 3. Results of Johansen's test for cointegration

No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.353361	42.07684	47.85613	0.0166
At most 1	0.249823	22.02232	29.79707	0.2973
At most 2	0.157161	8.799803	15.49471	0.3842
At most 3	0.020116	0.934771	3.841466	0.3336

Source: Authors' Compilation

The cointegration test findings are based on trace statistics, and Table 3 displays the maximum eigenvalues test. The cointegration test is used to determine the long-term relationship between variables. We must determine whether or not there is cointegration between variables. The value of the t-statistics for the null hypothesis cases exceeds the crucial value, which suggests that at least one cointegrating equation must exist. Trace statistics indicate that all variables are cointegrated and identical to the case of the highest eigenvalue. Therefore, when variables are cointegrated, the VECM model can be implemented.

Table 4. Granger causality test

Null Hypothesis	F-Statistic	Prob.
LEC to LCO2	2.59825	0.05
LCO2 to LEC	1.57297	0.2066
LGDP to LCO2	3.3217	0.0196
LCO2 to LGDP	0.058	0.999
LUP to LCO2	0.46595	0.8253
LCO2 to LUP	2.64973	0.0467
LGDP to LEC	1.19338	0.3496
LEC to LGDP	0.99155	0.4574
LUP to LEC	1.8484	0.1403
LEC to LUP	3.60538	0.0138
LUP to LGDP	1.06424	0.4158
LGDP to LUP	0.88949	0.5209

Source: Authors' Compilation

We selected six lags as the most suitable lag per the Akaike information criterion (AIC) and Hannan-Quinn information criterion (H.Q.). We used the Granger causality test to measure causality and weather variables as unidirectional or bidirectional causality (Table 4).

As can be seen in Table 5, the assumption that energy consumption and economic growth do not induce environmental degradation was proved incorrect. To further explore the relationship among CO_2 emissions, GDP per capita, Energy Consumption and Urban Population. We used the VECM model to measure long-run causality.

As noted in Table 4, Economic growth, Energy consumption, and urbanization have long-run causality on

CO_2 emission as the error correction term is significant (see Table 6).

Table 5. VAR lag order selection criteria

Lag	Log L	LR	FPE	AIC	SC	HQ
0	347.1893	NA	1.09E-14	-20.79935	-20.61796	-20.73832
1	376.1366	49.12268	5.02E-15	-21.58404	-20.67706*	-21.27887
2	400.6466	35.65092*	3.14E-15	-22.09979	-20.46724	-21.55049
3	420.1925	23.69204	2.87e-15*	-22.3147	-19.95657	-21.52126
4	431.5142	10.97856	4.92E-15	-22.03116	-18.94745	-20.99359
5	457.996	19.25951	4.25E-15	-22.66642	-18.85713	-21.38471
6	489.4589	15.25473	4.25E-15	-23.60357*	-19.0687	-22.07772*

* indicates lag order selected by the criterion

Source: Authors' Compilation

Table 6. Vector Error Correction Model (VECM)

	Coefficient	Std. Error	T-Statistic	Prob.
C(1)	-0.62556	0.221255	-2.82734	0.008
C(2)	-0.85197	0.260867	-3.2659	0.0026
C(3)	-1.1269	0.29517	-3.81781	0.0006
CON(4)	-0.68695	0.306822	-2.23891	0.0322
CON(5)	-0.5841	0.215637	-2.70874	0.0108
R-squared	0.883393	0.630601	0.371454	0.470838
Adj. R-squared	0.843029	0.502732	0.153881	0.287667
Sum sq. resids	0.00995	0.01307	2.20E-05	0.233565
S.E. equation	0.019563	0.022421	0.00092	0.09478
F-statistic	21.88563	4.931627	1.707259	2.57048

Source: Authors' Compilation

$$\begin{aligned}LCO2={}&C(1)*LCO2(-1)+C(2)*LCO2(-2)+C(3)*LCO2(-3)+C(4)*LCO2(-4)+C(5)*LCO2(-5)+C(6)*LCO2(-6)\\&+C(7)*LEG(-1)+C(8)*LEG(-2)+C(9)*LEG(-3)+C(10)*LEG(-4)+C(11)*LEG(-5)+C(12)*LEG(-6)\\&+C(13)*LGDP(-1)+C(14)*LGDP(-2)+C(15)*LGDP(-3)+C(16)*LGDP(-4)+C(17)*LGDP(-5)+C(18)*LGDP(-6)\\&+C(19)*LUP(-1)+C(20)*LUP(-2)+C(21)*LUP(-3)+C(22)*LUP(-4)+C(23)*LUP(-5)+C(24)*LUP(-6)+C(25)\end{aligned} \tag{2}$$

It can be seen from Table 7, that there is short-run causality flowing from GDP and Energy Consumption to CO_2 emission. We could not find short-run causality in the case of urbanisation to CO_2 emission. It is critical to stress that CO_2 emissions in India have been produced by rapid expansion, particularly in the previous decade, and measures should be developed to prevent further environmental deterioration without harming progress. Trade may play a key role in validating policies that preserve both growth and the environment.

Table 7. Short run causality analysis (Wald test)

	Test Statistic	Value	Df	Probability
LGDP to CO_2	F-statistic	36.54299	(6)	0.0000
LEC to CO_2	F-statistic	27.63973	(6)	0.0001
LUP to CO_2	F-statistic	6.510641	(6)	0.3685

Source: Authors' Compilation

5. DISCUSSION

Most research in the literature, including Halicioglu [14], Acaravci and Ozturk [10] Kasman and Duman [7], Farhani and Shahbaz [18] and Ozturk and Acaravci [15] have found positive relationship between energy and carbon emission. Alam et al. [17], Zhang and Cheng [12], Sehrawat et al. [23] and Wang et al. [13] all found similar results, suggesting that rising economic growth is associated with rising environmental contamination. It allows for the public's increasing demands to be met through utilisation and investment initiatives, which in turn leads to more pollution, waste, and environmental degradation.

As a result, the ecological sustainability of India is jeopardized by the rapid growth of its urban population as people move from rural areas to the city in search of better opportunities. The results show that increased consumption of energy from fossil fuels is linked to higher levels of CO_2 emissions in India, a country experiencing rapid urbanisation. Previous studies by Zhang and Cheng [12], Wang et al. [13] and Sehrawat et al. [23] support the findings of the present study [13]. More electrical devices (ventilation, equipment, lighting, cooling, etc.) were needed, leading to more CO_2 emissions in a region that already has one of the highest power intensities in the country. Growth in urban areas is good for the economy, but it may also increase CO_2 emissions.

6. CONCLUSIONS

This paper attempts to investigate the dynamic causal relationships between the emission of greenhouse gasses and energy consumption, economic growth and urbanisation of India through Vector Auto Regression analysis empirically. We used the VECM model to measure long-run causality as the variables are cointegrated. We discovered that Economic growth, Energy consumption and urbanisation have long-run causality on CO_2 emissions. We found a unidirectional causality flowing from energy consumption and economic growth to CO_2 emissions.

Short-run causality flows from GDP and Energy Consumption to CO_2 emission. We could not find short-run causality in the case of urbanisation to CO_2 emission. Year after year, the country's rapid industrial growth has resulted in excessive energy consumption, resulting in environmental degradation. The confirmation of the EKC hypothesis lays the groundwork for policy formation in the area of carbon emission reduction, as well as filling a gap in the country's climate-friendly economic policy.

It is time for India to move forward with technological reforms in several industrial sectors to achieve long-term development. To eliminate distortionary taxes and adopt some environmental charges, additional tax reforms are required. As a result, there is a critical need to develop a timely and comprehensive environmental protection policy to minimise the looming emissions threats. Moreover, although it is beyond the scope of this article, it might be valuable to build on this study by carrying out further research using more variables and comparing results to findings in similar research in other countries.

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