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Article

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Investigating the Nature of Growth-Environment Relationship for India

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ABSTRACT

Environmental concerns need to be addressed to make economic growth sustainable. Theories in the literature attempt to establish the relationship between economic growth and environmental degradation. These theories are not deterministic, as concepts like the inverted U-shaped or N-shaped Environmental Kuznets Curve (EKC) have yielded different results for different economies. This study attempts to validate the shape of the EKC and simultaneously test for an asymmetric relationship between economic growth and carbon dioxide emissions. To achieve this, the study uses the simple and non-linear Autoregressive Distributed Lag (ARDL) method on data from 1965 to 2021. The study finds evidence of an inverted U-shaped EKC but finds no evidence of an N-shaped EKC for India. Additionally, the study reports an asymmetric relationship between economic growth, energy consumption, and carbon dioxide emissions. Based on these findings, the study provides suitable policy recommendations.

Keywords: Economic Growth, Environmental Degradation, Threshold, EKC, NARDL
JEL Classifications: Q43, Q56

1. INTRODUCTION

The Environmental Kuznets Curve (EKC) provides a theoretical framework to describe the association between environmental degradation and economic development. It is named after a similar curve used by Simon Kuznets to explain the relationship between economic growth and income inequality. The EKC can be described as having three distinct stages. First, a low-income stage where an economy concentrates on production, urbanization, and industrialization, resulting in aggravated environmental degradation in the form of resource depletion and increased pollution. The second stage marks a reversal of the earlier trend in environmental degradation as, with increased income levels, there is an adoption of regulations, investment, and technology that make the production process cleaner and more efficient. Finally, in the third stage, after the economy attains a high level of economic development, awareness forces both the general public and the government to adopt all kinds of sustainable practices. Here, environmental awareness, technological advancements, institutions and regulatory frameworks, and a shift in consumption patterns all reinforce elements of sustainability. The concept behind the EKC is that after a particular threshold of affluence is attained, economies take care of environmental concerns.

A different trajectory is proposed in the 'N-shaped Environmental Kuznets Curve'. It suggests that a second turning point is involved in the relationship between economic growth and income growth. After the decline in environmental degradation as suggested by the traditional EKC curve, it again increases, reflecting setbacks in the agenda to attain sustainable development. This re-worsening of environmental conditions after early progress involves the complexities associated with environmental concerns.

The N-shaped EKC implies that the relationship between economic development and environmental degradation is more complex and could involve setbacks and recommitment to environmental protection over time. It suggests that achieving sustainable development requires multiple shifts in policy, technology, and societal values. However, it is worth noting that the N-shaped EKC is not as widely accepted or supported by empirical evidence as the traditional EKC, and its application and relevance can vary depending on specific contexts and environmental indicators.

Alternatively, another thought indicates the presence of an asymmetric relationship between economic growth and pollution. It reflects that the relationship is not consistent throughout the levels of economic growth. That is, an increase or decrease in economic growth is not necessarily associated with a proportionate increase or decrease in pollution. Here, the effect of economic growth on pollution levels is not the same in both directions. This could be due to the nascent stage of development where the focus is only on production and industrialization, and environmental concerns take a back seat. But with affluence, the rate at which pollution happens slows down in a non-linear fashion. All the associated factors like advancements in technology, the attitude of society, the composition of industry, government policies, and the efficiency of institutions play roles in making the relationship between environmental concern and economic growth asymmetrical.

This happens for reasons such as the relocation of industries from developed to developing economies to take advantage of weak environmental regulations. Also, as economies develop, there is a transition from an industry-based to a service-based economy, which leads to changes in the nature of pollution that are not proportionate to economic growth.

It is essential to comprehend the context-dependent and highly complex nature of the relationship between economic growth and environmental concerns. There is a complex interplay of various factors unique to each economy. Overall, the inverted U-shaped and N-shaped EKC and asymmetric relationship theories reflect upon the complex nature of the challenge faced in maintaining the balance between economic growth and environmental conservation. Though these relationships are not yet a universal law, as different economies have different results, they do provide a theoretical framework. Moreover, each economy has unique social, economic, and policy environments, and identifying the stage at which an economy is helps in the formulation of suitable policies to address the issue of environmental degradation and sustainability.

This study plans to examine this association between economic growth and environmental concern using carbon dioxide (CO_2) emissions. Climate change is aggravated by CO_2 emissions. These emissions are a by-product of economic growth, which is a matter of grave environmental concern as it leads to global warming. Worldwide, CO_2 emissions contribute to more than 60% of the increase in greenhouse gases (Ozturk and Acaravci, 2010), while India ranks third in the world in terms of carbon emissions (Ahmad et al., 2016). According to the Emissions Gap Report 2019, India is one of the top four emitters, accounting for around 7% of total global emissions. Towards this, the study proceeds with twin objectives of validating the shape of the EKC and testing for an asymmetric relationship between economic growth and CO_2 emissions.

2. LITERATURE REVIEW

There are numerous studies in the context of environmental economics that have tried to assess the nexus between economic growth, energy consumption, and pollution. Based on empirical findings, these studies can be categorized into three groups. The first strand of literature proposes that there is no relationship between economic growth and carbon emissions, which is referred to as the "neutrality hypothesis." This implies that an economy can attain higher economic growth without compromising the quality of the environment. Empirical studies finding no evidence of a causal relationship between economic growth and carbon emissions, such as those by Zachariadis (2007) and Bowden and Payne (2009), support this view.

The next group of literature postulates a linear relationship between economic growth and carbon emissions. Studies supporting a causal relationship between economic growth, energy consumption, and carbon emissions have found unidirectional causality running from economic growth to energy consumption (Kraft and Kraft, 1978; Akarca and Long, 1980) and also from energy consumption to economic growth (Aqeel and Butt, 2001; Shiu and Lam, 2004). Additionally, bidirectional causality has been found by Sultan and Alkhteeb (2019) and Narayan and Smyth (2009). Urbanization has also been found to cause CO_2 emissions (Mahmood, 2022).

The third group of literature suggests a non-linear relationship between economic growth and carbon emissions. This concept of the EKC is derived from Kuznets' (1955) prediction of an inverted U-shaped relationship between per capita income and income inequality. He postulated that initially, there is an increase in inequality as income increases, but once a particular threshold of income is attained, inequality decreases. Later, Grossman and Krueger (1991) adapted the same reasoning to depict the relationship between carbon emissions and per capita income. The presence of an inverted U-shaped EKC has been reported by many studies, including Selden and Song (1994), Alsamara et al. (2018), and Mahmood et al. (2022).

Kuznets (1955) postulated an inverted U-shaped relationship between per capita income and income inequality, which later came to be known as the Environmental Kuznets Curve (EKC). He theorized that at the outset, there is an increase in inequality as income increases, and then after reaching the threshold, inequality decreases. Grossman and Krueger (1991) modified this logic to represent the relationship between carbon emissions and per capita income. Recent studies have reported an N-shaped EKC, which postulates that environmental degradation will start to increase again after a particular level of income (Allard et al., 2018).

Three factors—scale, composition, and technique—determine the shape of the EKC (Kanjilal and Ghosh, 2013). The initial stage of economic growth is normally associated with industrialization, where there is a positive association between economic growth and pollution. This is referred to as the scale effect. After a particular level of income is reached, economies grow and industries adopt cleaner strategies and technologies, known as the technique effect. Finally, there is a reduction in the share of polluting elements in the production process, referred to as the composition effect (Solarin and Lean, 2016).

Nevertheless, some studies, such as Churchill et al. (2018), Dogan and Tarekuk (2016), and Raggad (2018), have reported the absence of an inverted U-shaped EKC. For India, the presence of an inverted U-shaped EKC is contested, with some studies, like those by Dietzenbacher and Mukhopadhyay (2008), Mukhopadhyay (2008), Mukhopadhyay and Chakraborty (2005a/2005b), Sinha and Bhatt (2016), and Sajeev and Kaur (2020), reporting its presence, while others, like Ghoshal and Bhattacharyya (2008) and Khanna and Zilberman (2001), found no evidence of it. Moreover, the N-shaped Kuznets curve is rarely visible in the literature except for a few studies (Hossain et al., 2023; Uche et al., 2023). Studies on the asymmetric relationship between emissions, growth, and energy are also scant. This calls for a new assessment of both the EKC and the asymmetric relationship using the latest available data.

3. METHODOLOGY

The study plans to estimate the following function:
CO_2 = f(GDP, GDP^2, GDP^3, EC, U); where GDP is GDP per capita; GDP^2 is the square of the GDP per capita, GDP^3 is the cube of the GDP per capita, EC is primary energy consumption per capita, U is urbanization and CO_2 is carbon dioxide emission. The data for GDP per capita and urbanization is taken from the World Bank while the data for energy consumption per capita and carbon dioxide emission is taken from BP's Statistical Review of World Energy. The study first proceeds with estimating the stationary properties of the data. Towards this the study uses Augmented Dickey Fuller test. Here the null hypothesis is that the data is non-stationary. A P-value of more than 0.05 leads to the acceptances of the null hypothesis. It indicates that the data is not stationary and vice versa. This identification of stationarity is important as it leads to selection of appropriate methodology to establish relationship between the variables. If the variables are stationary at level, we go for simple regression. If the variables are not stationary at level, but stationarity at first difference then we apply Johansen method of cointegration. And, if the variables are stationary at different levels, then we apply the Auto regressive distributed lag (ARDL) model.

In ARDL model the variables can be a mix of stationary at level and stationary at first difference. The only restrictive condition is that no variable should be stationary only at second difference. For further exploration, the study also uses nonlinear ARDL method to study the differential effect of a positive and negative change in the independent variable on the dependent variable. To ascertain the presence of cointegration between the variables Bounds test is used. If the F-statistic is more than the upper bound value, it implies that there is a cointegrating relationship between the variables. Next, the error correction term (ECT) should be negative and significant to indicate that if there is a deviation from the long run equilibrium, it will be corrected.

The study estimates four different models. Model 1 estimates the simple ARDL model assuming a linear relationship between the variables. Model 2 estimates the ARDL model with a quadratic growth (GDP per capita) term. Validity of this particular model would indicate the inverted shape of the EKC curve. Model 3 estimates the ARDL model with a cubic growth term. Validity of this model would imply a N-shaped EKC curve. And finally model 4 estimates a non-linear association between CO_2 emissions, energy consumption and GDP per capita using a nonlinear auto regressive distributed lag (NARDL) functional form. The specifications of the model are as follows:

$$\text{Model 1}: \Delta CO_{2t} = \beta_0 + \beta_1 CO_{2t-1} + \beta_2 GDP + \beta_3 EC + \beta_4 U + \sum_{i=1}^{v}\gamma_{1i}\Delta CO_{2t-i} + \sum_{i=0k=1}^{z}\theta_{2i}\Delta GDP + \sum_{i=0k=1}^{z}\theta_{3i}\Delta EC + \sum_{i=0k=1}^{z}\theta_{4i}\Delta U + \varepsilon_t$$

$$\text{Model 2}: \Delta CO_{2t} = \beta_0 + \beta_1 CO_{2t-1} + \beta_2 GDP + \beta_3 (GDP)^2 + \beta_4 EC + \beta_5 U + \sum_{i=1}^{v}\gamma_{1i}\Delta CO_{2t-i} + \sum_{i=0k=1}^{z}\theta_{2i}\Delta GDP + \sum_{i=0k=1}^{z}\theta_{3i}\Delta (GDP)^2 + \sum_{i=0k=1}^{z}\theta_{4i}\Delta EC + \sum_{i=0k=1}^{z}\theta_{5i}\Delta U + \varepsilon_t$$

$$\text{Model 3}: \Delta CO_{2t} = \beta_0 + \beta_1 CO_{2t-1} + \beta_2 GDP^{+}_{t-1} + \beta_4 (GDP)^2 + \beta_5 (GDP)^3 + \beta_1 U + \sum_{i=1}^{v}\gamma_{1i}\Delta CO_{2t-i} + \sum_{i=0k=1}^{z}\theta_{6i}\Delta GDP + \sum_{i=0k=1}^{z}\theta_{6i}\Delta (GDP)^2 + \sum_{i=0k=1}^{z}\theta_{7i}\Delta (GDP)^3 + \sum_{i=0k=1}^{z}\theta_{5i}\Delta U + \varepsilon_t$$

$$\text{Model 4}: \Delta CO_{2t} = \beta_0 + \beta_1 CO_{2t-1} + \beta_2 GDP^{+}_{t-1} + \beta_3 GDP^{-}_{t-1} + \beta_4 Energy^{+}_{t-1} + \beta_5 Energy^{-}_{t-1} + \beta_4 (GDP)^2 + \beta_5 (GDP)^3 + \beta_1 U + \sum_{i=1}^{v}\gamma_{1i}\Delta CO_{2t-i} + \sum_{i=0}^{w}\gamma_{2i}\Delta GDP^{+}_{t-i} + \sum_{i=0}^{x}\gamma_{3i}\Delta GDP^{-}_{t-i} + \sum_{i=0}^{y}\gamma_{4i}\Delta EC^{+}_{t-i} + \sum_{i=0k=1}^{z}\gamma_{5i}\Delta EC^{-}_{t-i} + \sum_{i=0k=1}^{z}\theta_{6i}\Delta (GDP)^2 + \sum_{i=0k=1}^{z}\theta_{7i}\Delta (GDP)^3 + \sum_{i=0k=1}^{z}\theta_{5i}\Delta U + \varepsilon_t$$

β_1 is the long-run positive shock of GDP per capita on CO_2 emissions; β_2 is the long-run negative shock of GDP per capita on CO_2 emissions; β_3 is the long-run positive shock of energy consumption on CO_2 emissions; and β_4 is the long-run negative shock of energy consumption on CO_2 emissions. γ_1 is the short-run positive shock of GDP per capita on CO_2 emissions; γ_2 is the short-run negative shock of GDP per capita on CO_2 emissions; $\gamma_3$is the short-run positive shock of energy consumption on CO_2 emissions; and γ_4 is the short-run negative shock of energy consumption on CO_2 emissions.

Finally, residual diagnostics is performed for each of the models. Breusch-Godfrey LM Test is applied to test for serial correlation. Here the null hypothesis is that the residuals are not serially correlated correlation. Breusch-Pagan-Godfrey is applied to test for heteroscedasticity. Here the null hypothesis is that the residuals are homoscedastic. Jarque-Bera test is applied to test for normality. Here the null hypothesis is that the residuals are normally distributed. All the hypothesis are tested at 5% level of significance. A P-value of more than 0.05 will indicate that the null hypothesis is accepted. Finally, CUSUM and CUSUM square graphs will be used to test for model stability. If the plots are within the critical bands, it indicates that the parameters are stable.

4. RESULTS

The study applies Augmented Dickey Fuller test to ascertain the stationarity of the variables. The variable urbanization is stationary at level as the p value for the t-statistic of constant and linear trend is less than 0.05, while the other variables (GDPC, EC, CO_2) are stationary at first difference (Table 1). As variables are stationary at mixed order and none of the variables need to be differenced twice to attain stationarity, the ARDL approach developed by Pesaran et al. (2001) is used.

The relationship between emissions and GDP per capita is not represented properly assuming a linear analysis. As is shown in Model 1, none of the variables are significant in the long run when we assume a linear relationship between the variables. The moment the relationship is represented by a quadratic model, the long run relationships are significant as is represented by Model 2 (Table 2). The coefficient of for the GDPC term is positive (4.59) and the coefficient of the square of GDPC is negative (−0.21). This indicates that initially CO_2 emissions increase with an increase in GDPC and then after point CO_2 emissions decrease with further increase in GDPC. This hints at the presence of inverted U-shaped relationship as advocated by EKC hypothesis. The threshold value is calculated using the formula: Exponent of 4.591360/2/0.21 4058= 45459 (approximately) which roughly coincides with the year 2002-03.

The F-statistic (8.18) is also than the upper bound value (3.49) indicating the presence of a cointegrating relationship between the variables. The ECT is -0.55 and significant indicating that 55% of the disequilibrium will be corrected in one year. Residual diagnostics show that the model is valid as the error terms are serially not correlated, homoscedastic and normally distributed.

Table 1: Unit root tests

Variables	GDPC		EC		U		CO_2	
	t-statistic	P	t-statistic	P	t-statistic	P	t-statistic	P
Constant	2.3354	1.0000	0.5096	0.9856	−0.5105	0.8808	−0.1896	0.9333
Constant, linear trend	−1.7558	0.7127	−2.8221	0.1958	−3.9247	0.0174	−2.3436	0.4043
None	7.6101	1.0000	7.9784	1.0000	1.8944	0.9851	10.8059	1.0000
Variables	**DGDPC**	**P**	**DE**	**P**	**DU**	**P**	**DCO_2**	**P**
Constant	−7.2804	0.0000	−8.3301	0.0000	−2.0452	0.2673	−8.4148	0.0000
Constant, linear trend	−8.0941	0.0000	−8.3036	0.0000	−2.0432	0.5648	−8.3533	0.0000
None	−1.4925	0.1256	−1.4021	0.1479	−0.1499	0.6273	−0.9462	0.3025

EC: Energy consumption

Table 2: Autoregressive distributed lag results

Restricted constant and no trend (automatic lag selection)				
Variable	Model 1: ARDL (4, 0,1, 0)		Model 2: ARDL (4, 0, 4, 1, 4, 4, 4)	
	Coefficient	P	Coefficient	P
GDPC	−1.1	0.57	4.59	0.00
GDPC2			−0.21	0.00
GDPC3				
GDPC_POS				
GDPC_NEG				
EC			0.97	0.00
EC_POS				
EC_NEG				
U	1.79	0.23	1.45	0.00
C	7.88	0.61	−24.96	0.00
CointEq (-1)*	−0.03	0	−0.55	0.00
Bounds test (F-statistic)	3.06	2.79; 3.67	8.18	2.56; 3.49
Breusch-Godfrey serial correlation LM test	2.45	0.29	5.30	0.07
Jarque-Bera	4.2	0.12	0.25	0.87
Heteroskedasticity test: Breusch-Pagan-Godfrey	6.38	0.6	24.11	0.19
CUSUM and CUSUMSQ	Within the range		Within the range	

ARDL: Autoregressive distributed lag, EC: Energy consumption

The test for serial correlation accepts the null hypothesis of no serial correlation (P-value is 0.07); the test for heteroscedasticity accepts the null hypothesis that the residuals are homoscedastic (P-value is 0.87) and the test for normality also accepts the null hypothesis that the error terms are normally distributed (P-value is 0.19) (Table 2). The CUSUM and CUSUM squares graphs indicate that the model is stable (Figure 1).

Next, the study incorporates cubic form for the variable GDPC (Model 3). But we better ignore this model as the p-values associated with the coefficients are more than 0.05, hence are considered as not significant (Table 3). Finally, as variables can depict non-linear nature, hence this study extends the ARDL framework to the NARDL framework as proposed by Shin et al. (2014) to integrate the non-linear relationship between the variables. Here the effect of GDPC and energy consumption (EC) is decomposed into positive and negative impact. The results of NARDL model are presented in Table 3.

This results of the NARDL model (Model 4) show that when there is an increase in GDPC, CO_2 emissions increase by 7.84 units; and when there is a decrease in GDPC, CO_2 emissions increase by 2.97 units. Although in both cases the relationship is significant as the $P < 0.05$, the increase in GDPC is lower when there is a decline in GDPC. Similar interpretations can be made for the energy consumption also. When there is an increase in energy

Figure 1: CUSUM graphs

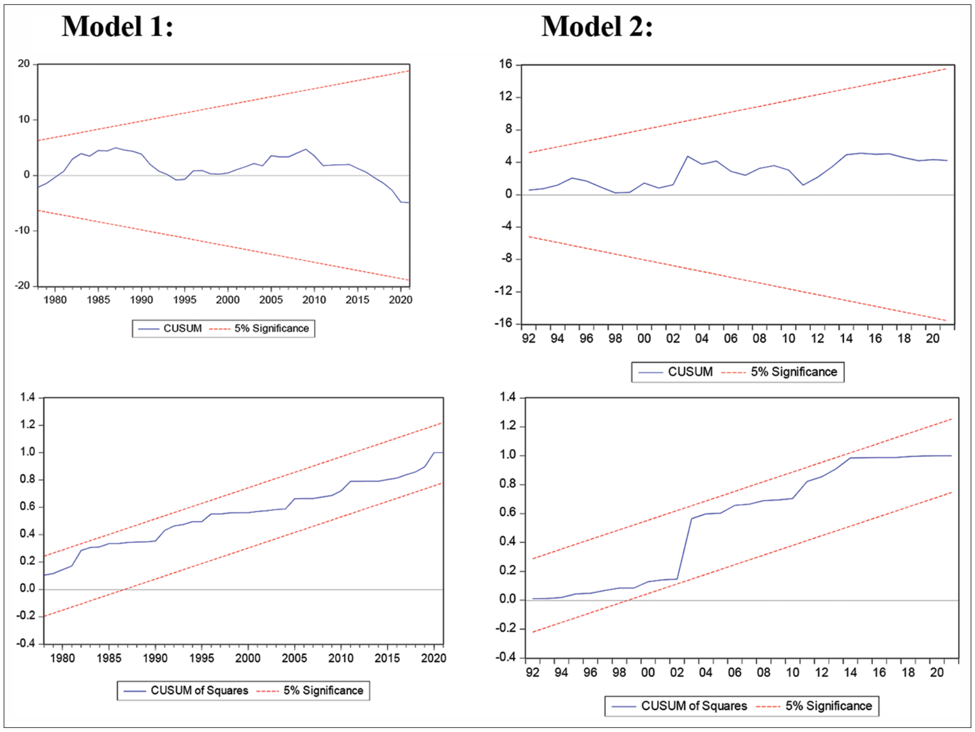
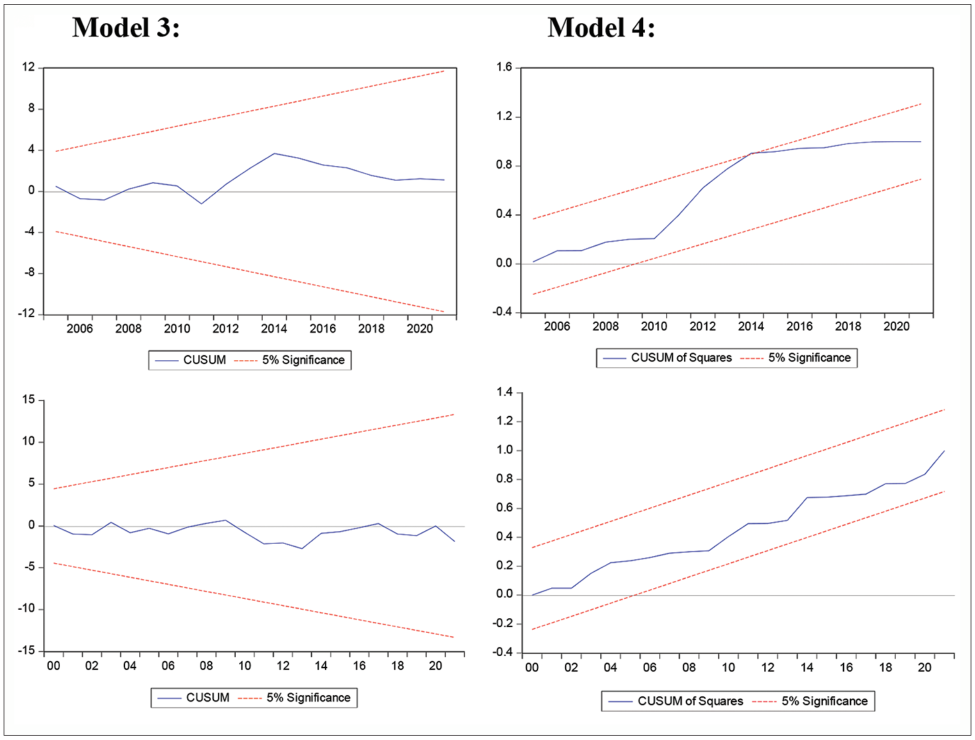


Table 3: Nonlinear auto regressive distributed lag results

Restricted constant and no trend (automatic lag selection)				
Variable	Model 1: ARDL (4, 1, 2, 4, 4, 0)		Model 2: ARDL (4, 0, 4, 1, 4, 4, 4)	
	Coefficient	P	Coefficient	P
GDPC	3.75	0.87		
GDPC2	−0.14	0.95	−8.92	0.00
GDPC3	0.00	0.97	9.23	0.00
GDPC_POS			7.84	0.00
GDPC_NEG			2.97	0.01
EC	−0.33	0.00		
EC_POS			1.45	0.00
EC_NEG			−0.41	0.45
U	1.45	0.00	0.13	0.90
C	−4.08	0.00	19.19	0.00
CointEq(-1)*	−0.55	0.00	−0.78	0.00
Bounds test (F-statistic)	6.80	2.39; 3.38	28.99	2.27; 3.28
Breusch-godfrey serial correlation LM test	5.44	0.07	2.41	0.30
Jarque-Bera	0.24	0.89	0.01	1.00
Heteroskedasticity test: Breusch-Pagan-Godfrey	24.2	0.23	26.85	0.47
CUSUM and CUSUMSQ	Within the range		Within the range	

ARDL: Autoregressive distributed lag, EC: Energy consumption

Figure 2: CUSUM graphs



consumption (EC), CO_2 emissions increase significantly by 1.45 units; but when there is a decrease in energy consumption, the relationship with CO_2 emissions become not significant as the p-value turns out to be more than 0.05.

The F-statistic of the NARDL model is 28.99 which is greater than the upper bound value of 3.28, confirming the presence of cointegrating relationship between the variables. The model also satisfies the conditions of error correction mechanism as the ECT (−0.78) is negative and significant (Table 3). The test for serial correlation accepts the null hypothesis of no serial correlation (P-value is 0.30); the test for heteroscedasticity accepts the null hypothesis that the residuals are homoscedastic (P-value is 1.00) and the test for normality also accepts the null hypothesis that the error terms are normally distributed (P-value is 0.47) (Table 3). The graphs of CUSUM and CUSUM squares are also within the range indicating that the NARDL model is stable (Figure 2).

5. CONCLUSION

This study attempts to examine the asymmetric relationship between CO_2 emissions, per capita GDP, energy consumption, and urbanization. The relationship between these variables is not significantly represented by a linear model. The quadratic model, however, has significant coefficients, with the coefficient of the quadratic term being negative, implying an inverted U shape. The study estimates that the downturn in CO_2 pollution roughly coincided with the year 2002-03. Furthermore, the study does not find evidence for an N-shaped Kuznets curve, as the coefficients of the quadratic and cubic terms of per capita GDP are not significant.

The study also reports a nonlinear model indicating an asymmetric relationship between the variables. It shows that when per capita GDP increases, CO_2 emissions increase, with a coefficient of 7.83, whereas when per capita GDP decreases, the coefficient is 2.98. The coefficient when per capita GDP increases is much higher than when per capita GDP decreases. The variable energy consumption is positive and significant when considering a positive change in energy consumption. However, it is not significant when considering a decrease in energy consumption, implying that a decline in energy consumption does not necessarily lead to lower emissions.

This result leads to the recommendation that India needs to pursue climatic prudence aggressively. As the EKC holds true for India, improvements in economic growth are advocated alongside more stringent environmental regulations. This should be catalyzed by technological innovation and increased awareness of environmental concerns, facilitated through international cooperation. Thus, India's economic growth can be sustainable, with the expectation that environmental concerns can be taken care of with increased economic growth.

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