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RELATIONSHIP BETWEEN THE ECONOMIC GROWTH AND CARBON EMISSIONS LEVEL IN JHARKHAND, INDIA: AN EKC APPROACH

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ABSTRACT

The aim of this paper is to investigate the long run causal relationship between the economic development, carbon emissions level and energy consumption and examine the existence of EKC hypothesis in Jharkhand, India. The time series analysis is done for the period 2000-2020, covering a time span of, 21 years and the variables selected for analysis are CO_2 emissions level, real Gross State Domestic Product, and energy consumption of Jharkhand, India. The time series data was collected from different sources. To investigate the short and long run relationship among these variables, the Johanson system co-integration test was performed and to test the causal relationship between the variables, VEC Granger Causality/Block Exogeneity Wald test was applied. Finally, to test the EKC hypothesis, OLS (Ordinary Least Square) regression was performed. The results of Johanson system co-integration test implies that there is a long run relationship or co-integration among the variables CO_2 emissions, real GSDP, and energy consumption. The VEC Granger Causality/Block Exogeneity Wald test results implies that there is unidirectional relationship between real GSDP and both Carbon emissions and energy consumption. The results of quadratic form of EKC model indicates that there is an inverted U-shaped curve and the results of cubic form of EKC model shows that the inverted U-shaped curve does not exist between CO_2 emissions and real GSDP, it would be N-shaped curve in Jharkhand, India.

Keywords: *CO_2 emissions, EKC hypothesis, Energy consumption, Granger Causality, GSDP and VECM.*

Mathematics Subject Classification: *62J05, 62M10.*

1. INTRODUCTION

Economic development and environmental degradation are correlated to each other's, high level of economic growth leads to increase the level of environmental degradation and due to increasing economic growth there is a fear of a deteriorating environment and global warming. Greenhouse gas emissions, especially CO_2 is the main cause of the global warming. Human activities have clearly caused global warming mainly through the emissions of greenhouse gases, with the global surface temperature rising 1.1° C above 1850-1900 in 2011-2020. With large increases over land (1.59[1.34 to 1.83]$^{\circ}$C) then over the ocean (0.88[0.68 to 1.01]$^{\circ}$C). Globel surface temperature in the first two decades of the 21st century (2001-2020) was 0.99[0.84 to 1.10]$^{\circ}$C higher than 1850-1900. Global surface temperature has increased faster since 1970 than in any other 50-years period over at least the last 200 years (IPCC). Continued greenhouse gas emissions will lead to increasing global warming, with the best estimates of reaching 1.5° in the near term [1].

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In order to find the link between economic development and environmental degradation. The main purpose is to test Environmental Kuznets Curve hypothesis which indicates that in early stage of economic development leads to increase the level of environmental degradation, but after a certain level of economic development the trend between these two component reverses, so that high level of economic development implies that improvement of environmental degradation. Many studies have focused on analysing the relationship between economic growth and environmental degradation. In China, Zang & Cheng investigated the energy consumption, carbon emissions and economic growth relationship and found a unidirectional Granger Causality running from GDP to energy consumption. Moreover, the study reported that a unidirectional Granger Causality was observed from energy consumption to carbon dioxide emissions in the long run [2]. A study is done by Shikwambana et al found that the emissions level is generally correlated with economic growth in South Affrica between 1994 and 2019 [3]. A study is done by Saboori et al in Malaysia to examine the relationship between economic growth and CO_2 emissions level which results indicates that using disaggregated energy data, there is evidence of EKC hypothesis and there is bi-directional causality between economic growth and carbon emissions, with coal, gas, electricity, and oil consumption [4]. A study over some selected South Asian countries is done by Ahmed et al which results shows that there is a bi-directional causality between energy consumption and trade openness and unidirectional causality running from energy consumption, trade openness and population to CO_2 emissions [5]. A study over some selected African countries is conducted by Esso et al in which they found that there is bi-directional causality between economic growth and CO_2 emissions in short run for Nigeria and in the long run for Congo and Goban and in the long run energy consumption and economic growth cause CO_2 emissions in Benin, Cote d' lvoire, Nigeria, Senegal, south Africa, and Togo [6]. In United States, Soytas et al investigated the effect of energy consumption and output on carbon emissions. They found that income does not Granger cause carbon emissions in the US in the long run, but energy use does [7]. In Pakistan, Shahbaz et al investigates the relationship between CO_2 emissions, energy consumption, economic growth, and trade openness over the period of 1971-2009 and found that there is a long run relationship among the selected variables and the EKC hypothesis is supported. And unidirectional causality between economic growth to CO_2 emissions. Energy consumption increases CO_2 emissions both in the short and long run. Trade openness reduces CO_2 emissions in the long run but it is insignificant in the short run [8]. A study is done by Ghosh in India in which he observed that long- and short-run Granger causality running from real GDP and electricity supply to employment. Thus, growth in real GDP and electricity supply are responsible for the high level of employment in India [9]. In India, Misra investigates the relationship between economic growth and carbon emissions for the period 1970-2012 and found that there exists a long run relationship between the selected variables whereas in the short run, there is no relationship between the selected variables [10]. A study over India by Makarabbi et al in which they found that the bi-directional causality between CO_2 emissions per capita and FDI, CO_2 emissions per capita and energy consumption, but unidirectional Granger causality running from GDP per capita to CO_2 emissions per capita. And there is no evidence of EKC hypothesis [11]. Similarly, Alam investigate the impact of economic development on quality of environment in India and found that there is a long run relationship among CO_2 emissions, GDP per capita and industrial value added. GDP per capita is found to be negatively related with carbon emissions in India, but with no change in GDP per capita, carbon emission rise with rise in industrial value added [12]. A study is done by Ghoshal et al found that coal is the most important source of CO_2 in all the states. The relationship between per capita gross state domestic product and CO_2 follows an inverted U-shape [13]. Many other studies done by researchers to establish the relationship between economic growth and environmental degradation. In this paper we specially focus on the relationship between the economic growth and environmental degradation.

The rest of this paper is arranged as follows. In section 2, description of the study area. In section 3, discussion on methodology and data collection. In section 4, presentation of empirical results of the time series analysis. And the last section states that the conclusion of this study.

2. STUDY AREA

Jharkhand is an Indian state which is eastern part of country, created on 15th November 2000. It covers an area of 79,714 kilo meters square with 29.61% forest area and owns about 40% of total mineral resources of India. It is also known as land of forest. The city of Ranchi is its capital. And its geographical location is $23^{\circ} - 21^{'} - 0^{''}\text{N}$ latitude and between $85^{\circ} - 19^{'} - 48^{''}\text{E}$ longitude. Its average elevation above sea level is 909 feet. The Gross Domestic Product for the FY 2022-23 is around Rs. 4.23 Lakh Crore and the per capita income is Rs. 107336. Jharkhand has the fastest growing state economy in terms of GSDP. As per census 2011, the population of Jharkhand is 3,29,88,134 in which the contribution of urban area is 24.05% and the remaining 75.95% contribution from the rural area. The location map as well as the study area is shown in the figure 1.

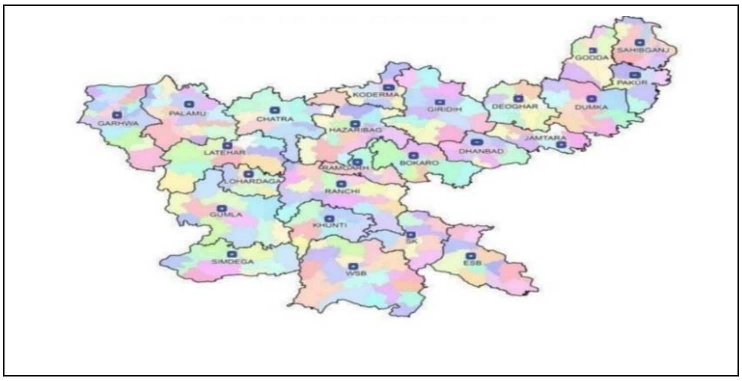


Figure-1: Map of Jharkhand, India

3. DATA AND METHODOLOGY

In this study, the following variables have been selected to determine the long run and causal relationship between the economic development, carbon emissions and energy consumption and to test the EKC hypothesis: real GSDP, CO_2 emissions and ENE. The Gross State Domestic Product at constant price (1999-2000) represents the economic development of Jharkhand. Carbon emissions level indicates the environmental degradation due to high level of energy consumption. And the analysis is done based on available dataset for the period 2000-2020 which covers 21 years to establish the relationship. This period is selected due to availability of data for all the selected variables. The data are collected from the different sources. The dataset of Gross State Domestic Product (in Lakhs Rs.) has been collected from Directorate of Economics and Statistics, Jharkhand. And the carbon emissions and energy consumption has been taken from Council on Energy, Environment and Water (CEEW). In this paper, we specifically want to examine the long run relationship or co-integration among all the selected variables and the dynamic adjustment towards long run equilibrium. if there is a long run relationship then we need to determine the causal long and short run relation among all the selected variables. Lastly, we examine the EKC hypothesis which tells us there is an inverted U-shaped relation between the environmental degradation and economic development.

In this time series analysis, we will perform some tests such as Augmented Dickey Fuller (ADF) unit root test which tells us the series is stationary, Johanson co-integration system test for detecting there is a long run relationship or co-integration among the variables and Vector Error Correction model for the validation of long run relationship and for finding the dynamic adjustment of the first difference of the variables. And the regression analysis is done to test the EKC hypothesis.

The ADF test is applied to know the selected series is stationary and the order of integration of the selected variables.
To apply the unit root test in the time series y_t, the ADF equation is given below is given below

$$\nabla y_t = \beta_0 + \beta_1 t + \varphi_1 y_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \varepsilon_t \qquad (1)$$

Where β_0 represents the intercept, β_1 represents the trend and y_t is the time series data. Here, if $\varphi_1 > 1$, then the time series is explosive. Again, if $\varphi_1 < 1$, then the series is stationary because there is no trend in the time series. Also, if $\varphi_1 = 1$, then the series is non-stationary which means that the series has unit root.

After this, if all the selected variables are stationary at level *i.e.*, I (0). Then we perform multiple regression model to investigate the relationship between the variables. And if all the variable are found to be stationary at first difference *i.e.*, I (1). Then Johanson Co-integration test is applied for finding the number of co-integrating vector and then we estimate VECM and on the VECM result do some diagnostic, residuals, and stability test for confirming the long run relationship between the co-integrating variables. Lastly, to test causal effect among the variables the VECM Granger Causality test is used.

To perform the Johanson Co-integration test all the variables are stationary at first difference, *i.e.*, I (1). Johanson Co-integration uses two types of statistics first one is trace-statistics and other one is maximum-eigenvalue statistics. The null hypothesis of Johanson Co-integration test is there is no co-integration among the selected variables. If the trace statistic value is greater than its critical value it means that there is a long run relationship or co-integration. And if the maximum eigenvalue is greater than its critical value then there is a long run relationship or co-integration. If trace statistics and max eigenvalue statistics shows different results, then trace statistics is more appropriate for further analysis.

If the I (1) series are co-integrated. Then we estimate VECM to examine both the short run and long run dynamics of the series.

In general, the conventional ECM for co-integrated series is as follows

$$\nabla Y_t = \beta_0 + \sum_{i=1}^{n} \beta_i \nabla Y_{t-i} + \sum_{j=1}^{n} \delta_j \nabla X_{t-j} + \varphi Z_{t-1} + u_t \quad (2)$$

Where Z is the Error Correction Term (ECT) and is the OLS residual from the following long run co-integration regression

$$Y_t = \beta_0 + \beta_1 X_t + e_t \quad (3)$$

And is defined as

$$Z_{t-1} = ECT_{t-1} = Y_{t-1} - \beta_0 - \beta_1 X_{t-1} \quad (4)$$

The term, Error Correction, relates to the fact that last period deviation from long run equilibrium influences the short run dynamics of the dependent variable. Thus, the co-efficient of ECT, φ is the speed of adjustment because it measures the speed at which Y returns to equilibrium after a change in X.

In VEC model, the long run relationship among the three variable is as follows

$$(\ln CO_2)_t = \beta_0 + \beta_1 (\ln GSDP)_t + \beta_2 (\ln ENE)_t + u_t \quad (5)$$

Where $\ln CO_2$ is the natural log of carbon emissions, lnGSDPis the natural log of GSDP and lnENE natural log of energy consumption. And u_t is the error in t year. And the co-efficient $\beta_0, \beta_1 \& \beta_2$ are the parameters.

The environmental Kuznets curve represents a relationship between environmental degradation and Gross State Domestic Product. It tells us carbon emissions level increases in the early stage of economic growth due to high level of emissions, but after some turning point the economic growth leads to low carbon emissions level. It means that carbon emissions level is an inverted U-shaped function of GSDP. To test the EKC hypothesis, we use regression analysis of the EKC model.

The quadratic form of the EKC model is given below

$$Y_t = \beta_0 + \beta_1 X_t + \beta_2 {X_t}^2 + e_t;\ Y = CO_2 \text{ emissions} \ \& \ X = GSDP \quad (6)$$

The EKC model holds that if $\beta_1 > 0$ & $\beta_2 < 0$, and both are statistically significant. Then there is a turning point and an inversed U-shaped curve exists.

Also, the cubic form of the EKC model is given below

$$Y_t = \beta_0 + \beta_1 X_t + \beta_2 {X_t}^2 + \beta_3 {X_t}^3 + e_t; Y = CO_2 \text{ emissions} \ \& \ X = GSDP \quad (7)$$

If $\beta_1 > 0, \beta_2 < 0$ and $\beta_3 > 0$, then there is a N-shaped curve exists which indicates that the carbon emissions level starts increasing again after a reduction to a specific level.

Table-1: Summary statistics of the variables

	CO2	GSDP	ENE
Mean	41093138	14278153	8955.619
Median	45733008	14318582	9768
Maximum	64343844	23839543	14643
Minimum	19401602	6497639	4728
Std. Dev.	15424235	5697183	3330.377
Skewness	-0.179771	0.215167	-0.035904
Kurtosis	1.529097	1.754052	1.697751
Sum	8.63E+08	3.00E+08	188068
Sum Sq. Dev.	4.76E+15	6.49E+14	2.22E+08

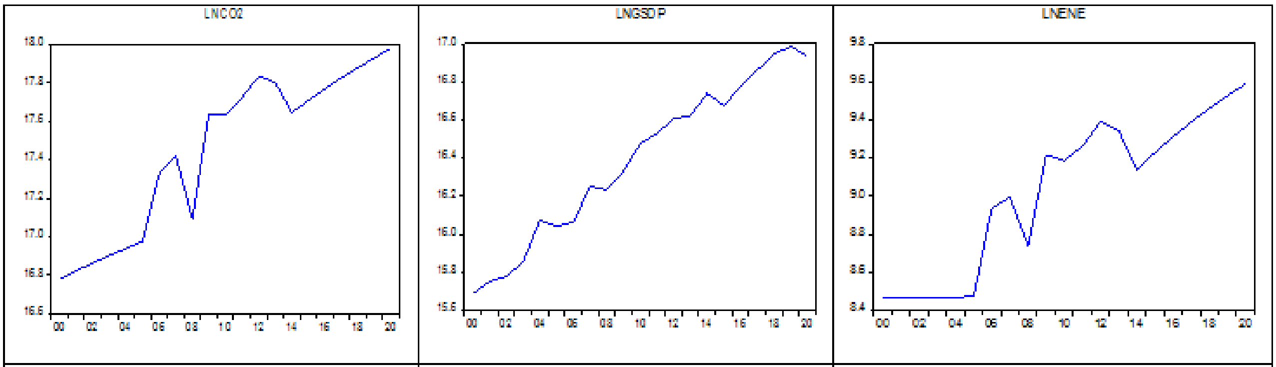
4. RESULTS AND DISCUSSION

In order to establish the relationship between economic growth and environmental degradation in Jharkhand, India. First, we must select appropriate variable for both the phenomenon. As we know that Gross Domestic Product represents the economic development of any nation and the Greenhouse Gases emissions (CO_2) involved in the environmental degradation. So, the relationship between economic growth (GSDP), Carbon emissions (CO_2) and energy consumption (ENE) in Jharkhand is tested on the absolute values and not on the per capita.

Table-2: Variables and their units of measurements

S.No.	Variable	Unit of measurement
1	CO2 Emissions	Metric tonnes
2	GSDP	Lakhs Rs.
3	Energy Consumption	Kilograms

All the variables first converted into their natural log values. This is done due to the time series data have growing trend because of the time factor. Thus, the natural log is used to remove the exponential growth factor from the variables. The data analysis is done to determine the relationship between these variables for the period 2000-2020, covering a time span of two decades. Clearly, the analysis is time series one. To start the analysis, we need the graphical representation of the variable on the raw data. So, the analysis begins by plotting the raw data (See figure 2).



(a)	(b)	(c)

Figure-2: Plotting of available raw data of the selected variables (a) log of CO2 emissions, (b) log of GSDP, and (c) log of energy consumption.

As we see all the selected variables have some trend which means that the selected variables are non-stationary. And when we perform directly the multiple regression analysis on these time series data which is non-stationary may lead to spurious regression. In order to determine the long run relationship among these variables all the variables should have stationary series in this time series analysis. Hence, checking for their stationarity by using appropriate test i.e., Unit Root Test. The augmented Dickey Fuller test has been used to check for the presence of unit root of the selected variables. None of them was found to be stationary at level, but each of them was found stationary at 1st difference. That means that each of them was found to be integrated of order one i.e. I (1) series with intercept and trend. Following are the results of unit root test (Table 3).

Table-3: Unit Root Test Result

	At level or I(0)		At 1st Difference or I(1)	
Variables	**Intercept**	**Intercept & Trend**	**Intercept**	**Intercept & Trend**
LNCO2	0.63	0.24	0.00	0.01
LNGSDP	0.33	0.24	0.00	0.00
LNENE	0.76	0.21	0.00	0.01

As per the above results, there is possibility of co-integration among all the three variables. Hence, checking for co-integration we need to perform the Johanson co-integration test. Now, by choosing the summary option in Johanson co-integration test the Akaike information criterion suggest that the optimal lag is 2 with the option linear- intercept and trend (Table 4).

Table-4: Selection of the appropriate lag length

Series: LNCO2 LNGSDP LNENE					
Lags interval: 1 to 2					
Selected (0.05 level*) Number of Cointegrating Relations by Model					
Data Trend:	None	None	Linear	**Linear**	Quadratic
Rank or No. of CEs	No Intercept No Trend	Intercept No Trend	Intercept No Trend	**Intercept Trend**	Intercept Trend
Trace	0	1	0	**1**	2
Max-Eig	0	1	1	**2**	2
*Critical values based on MacKinnon-Haug-Michelis (1999)					
Information Criteria by Rank and Model					
Data Trend:	None	None	Linear	Linear	Quadratic
Rank or No. of CEs	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Akaike Information Criteria by Rank (rows) and Model (columns)					
0	-6.111966	-6.111966	-6.308365	-6.308365	-6.170488
1	-6.123322	-6.111966	-6.937449	-7.637403	-7.610583
2	-5.840831	-6.111966	-6.479558	**-7.979718***	-7.972643
3	-5.213852	-6.111966	-5.947183	-7.403306	-7.403306

Based on the Akaike Information Criterion 2 lags were selected to perform the Johanson Co-integration test. Following are the results under this test. As per result of the Johanson Co-integration test, the trace statistic indicates that there is only one Co-integrating equation at 5% level of significance and the max-eigenvalue statistics indicate that there is at least two Co-integrating equation at 5% level of significance. If trace and max-eigenvalue shows different results, then trace statistics is more appropriate. Thus, based on trace statistics, there is only one Co-integrating equation (Table 5).

Table-5: Johanson Co-integration Test Result

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CEs	Eigenvalue	Trace Statistics	5% Critical Values	Prob.**
None *	0.878375	61.70894	42.91525	0.0003
At most 1	0.673751	23.78625	25.87211	0.0889
At most 2	0.182387	3.624582	12.51798	0.7955
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CEs	Eigenvalue	Trace Statistics	5% Critical Values	Prob.**
None *	0.878375	37.92269	25.82321	0.0008
At most 1 *	0.673751	20.16167	19.38704	0.0386
At most 2	0.182387	3.624582	12.51798	0.7955

Since the three endogenous variables are Co-integrated with at least one Co-integrating vectors, the appropriate model is Vector Error Correction Model (VECM) which is updated version of Vector Autoregressive (VAR) model. Hence, the VEC model is estimated with one Co-integrating equation and 1 lag in difference terms. Thus, VECM was performed with one Co-integrating equation and 1 lag as suggested by Johanson Co-integration test. Following are the results of VECM model (Table 6). And the probability values of the Error Correction coefficients are listed below which confirms that co-efficient of ECT are statistically significant at 5 % level of significance (Table 7).

The co-integrating equation and long run model are:

$$\mathrm{ECT}_{t-1} = [1 * (\mathrm{LNCO}_2)_{t-1} - 1.47(\mathrm{LNGSDP})_{t-1} - 0.59(\mathrm{LNENC})_{t-1} + 0.1 * @\mathrm{trend}(00) + 11.17] \quad (8)$$

Now, we will be developing Johanson Long Run Equation from VEC model

$$1 * (\mathrm{LNCO}_2)_{t-1} - 1.47(\mathrm{LNGSDP})_{t-1} - 0.59(\mathrm{LNENC})_{t-1} + 0.1 * @\mathrm{trend}(00) + 11.17 = 0 \quad (9)$$

So, now we will reverse the signs,

$$1 * (\mathrm{LNCO}_2)_{t-1} = 1.47(\mathrm{LNGSDP})_{t-1} + 0.59(\mathrm{LNENC})_{t-1} - 0.1 * @\mathrm{trend}(00) - 11.17 \quad (10)$$

The above long-run equilibrium relationship indicates that with no change in energy consumption, an increase in GSDP causes an increase in carbon emissions level and with no change in GSDP, an increase in energy consumption causes an increase in carbon emissions level.

There are three models in the output. Now, we will consider the model which is highlighted in the below VEC models output where LNCO2 is the dependent variable.

When we consider LNCO2 as the dependent variable. So, the equation which can be formed is

$$\Delta(\mathrm{LNCO_2})_t = -2.1 * \mathrm{ECT}_{t-1} - 0.32\ \Delta(\mathrm{LNCO_2})_{t-1} - 2.15\ \Delta\ (\mathrm{LNGSDP})_{t-1} + 0.59\ \Delta\ (\mathrm{LNENC})_{t-1} + 0.19 \qquad (11)$$

Here, prob-value of the coefficient C (1) is less than 0.05. So, the coefficient is quite significant at 5% level of significance. And, the speed of adjustment or correction is 2.1 ($\lambda = 2.1$).

The coefficient of ECT_{t-1} is -2.1. This means that deviation from long run relationship is corrected at the rate of 2.1 percent in this period.

This will confirm that there is existence of strong long run relationship among the variables in this model. The VEC Granger Causality/Block Exogeneity Wald Tests is used to check for the existence unidirectional and bi-directional causality among the variables. Following are the results under this test (Table 8).

The null hypothesis tested in VEC Granger Causality test is that there is no causal relation between the variables. Based on the analysis of p-values under this test, causality runs from GSDP to both Carbon emissions and energy consumption. Next, the short run causality analysis revels that there is presence of short run causality among the variables. This is done by using the Wald Co-efficient diagnostics test results of this listed below (Table 9). We further go ahead and perform some residuals test which is necessary for the existing model. Firstly, we perform multivariate normality test and as per results of this test, based on Jarque-Bera, we conclude that residuals are normally distributed in the model (Table 10). Secondly, we used the serial correlation LM test for testing the serial correlation of residuals. As per results of this test it tells us there is no serial correlation in residuals in the model (table 11). Thirdly, we estimate the heteroskedasticity test and it concludes that residuals are homoscedastic in the model (Table 12). Lastly, the square of CUSUM test is used for checking the stability of the model. And this test confirms that the model is stable at 5% of level of significance.

Table-6: Vector Error Correction Model Results

Cointegrating Eq:	**CointEq1**		
LNCO2(-1)	1		
LNGSDP (-1)	-1.47278		
	(-0.19434)		
	[-7.57849]		
LNENE (-1)	-0.585788		
	(-0.05854)		
	[-10.0074]		
TREND (0)	0.07416		
	(-0.01205)		
	[6.15538]		
C	11.16511		
Error Correction:	**D(LNCO2)**	**D(LNGSDP)**	**D(LNENE)**
CointEq1	**C(1)=-2.111917**	C(6)=0.939748	C(11)=-2.24702
	(-0.78762)	(-0.36839)	(-0.80299)
	[-2.68138]	[2.55095]	[-2.79832]
D(LNCO2(-1))	**C(2)=-0.321364**	C(7)=-0.444924	C(12)=-0.018833
	(-0.76972)	(-0.36002)	(-0.78474)
	[-0.41751]	[-1.23584]	[-0.02400]
D(LNGSDP(-1))	**C(3)=-2.14727**	C(8)=0.16387	C(13)=-2.284829
	(-0.64241)	(-0.30047)	(-0.65495)
	[-3.34250]	[0.54537]	[-3.48856]
D(LNENE(-1))	**C(4)-0.588834**	C(9)=0.358236	C(14)=0.328101
	(-0.70973)	(-0.33196)	(-0.72358)
	[0.82966]	[1.07916]	[0.45344]
C	**C(5)=0.194165**	C(10)=0.057993	C(15)=0.198408
	(-0.04531)	(-0.02119)	(-0.04619)
	[4.28535]	[2.73652]	[4.29519]
R-squared	0.600793	0.545028	0.592532
Adj. R-squared	0.486734	0.415036	0.476113
Sum sq. resids	0.215552	0.047156	0.224046
S.E. equation	0.124083	0.058037	0.126504
F-statistic	5.26739	4.192783	5.089636

Table-7: P-values of the Error Correction Co-efficient

ECT Co-efficient	Coefficient value	Std. Error	t-Statistic	Prob.
C(1)	-2.111917	0.787623	-2.681381	**0.0104**
C(2)	-0.321364	0.769722	-0.417506	**0.6784**
C(3)	-2.14727	0.642415	-3.342499	**0.0018**
C(4)	0.588834	0.70973	0.829658	**0.4114**
C(5)	0.194165	0.045309	4.285347	**0.0001**
C(6)	0.939748	0.368392	2.550946	0.0145
C(7)	-0.444924	0.360019	-1.235836	0.2234
C(8)	0.16387	0.300474	0.545371	0.5884
C(9)	0.358236	0.33196	1.079156	0.2867
C(10)	0.057993	0.021192	2.736522	0.0091
C(11)	-2.24702	0.80299	-2.798316	0.0077
C(12)	-0.018833	0.78474	-0.023998	0.981
C(13)	-2.284829	0.654949	-3.488562	0.0012
C(14)	0.328101	0.723578	0.453442	0.6526
C(15)	0.198408	0.046193	4.295192	0.0001

Table-8: VEC Granger Causality/Block Exogeneity Wald Tests

VEC Granger Causality/Block Exogeneity Wald Tests			
Dependent variable: D(LNCO2)			
Excluded	Chi-sq	df	Prob.
D(LNGSDP)	**11.1723**	**1**	**0.0008**
D(LNENE)	0.688333	1	0.4067
All	**15.52781**	**2**	**0.0004**
Dependent variable: D(LNGSDP)			
Excluded	Chi-sq	df	Prob.
D(LNCO2)	1.52729	1	0.2165
D(LNENE)	1.164577	1	0.2805
All	1.565109	2	0.4572
Dependent variable: D(LNENE)			
Excluded	Chi-sq	df	Prob.
D(LNCO2)	0.000576	1	0.9809
D(LNGSDP)	**12.17007**	**1**	**0.0005**
All	**17.10837**	**2**	**0.0002**

Table-9: Wald Co-efficient Test

Wald Test:			
Test Statistic	Value	df	Probability
F-statistic	7.763905	(2, 14)	0.0054
Chi-square	15.52781	2	**0.0004**
Null Hypothesis: C(3)=C(4)=0			
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
C(3)		-2.14727	0.642415
C(4)		0.588834	0.70973
Wald Test:			
Test Statistic	Value	df	Probability
F-statistic	0.600466	(2, 14)	0.5621
Chi-square	1.200932	2	0.5486
Null Hypothesis: C(8)=C(9)=0			
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
C(8)		0.16387	0.300474
C(9)		0.358236	0.33196
Wald Test:			
Test Statistic	Value	df	Probability
F-statistic	7.598356	(2, 14)	0.0058
Chi-square	15.19671	2	**0.0005**
Null Hypothesis: C(13)=C(14)=0			
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
C(13)		-2.28483	0.654949
C(14)		0.328101	0.723578

Table-10: Multivariate Normality Test

VEC Residual Normality Tests				
Orthogonalization: Cholesky (Lutkepohl)				
Null Hypothesis: Residuals are multivariate normal				
Component	**Skewness**	**Chi-sq**	**df**	**Prob.**
1	-0.211379	0.14149	1	0.7068
2	0.260502	0.214894	1	0.643
3	0.571145	1.032988	1	0.3095
Joint		1.389371	3	0.708
Component	**Kurtosis**	**Chi-sq**	**df**	**Prob.**
1	1.927755	0.910186	1	0.3401
2	2.077527	0.673674	1	0.4118
3	2.577208	0.141513	1	0.7068
Joint		1.725374	3	0.6313
Component	**Jarque-Bera**	**df**	**Prob.**	
1	1.051676	2	0.5911	
2	0.888568	2	0.6413	
3	1.174501	2	0.5559	
Joint	**3.114745**	**6**	**0.7943**	

Table-11: Serial Correlation LM Test

VEC Residual Serial Correlation LM Tests						
Null hypothesis: No serial correlation at lag h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	8.021706	9	0.532	0.903648	(9, 22.1)	**0.539**
2	4.369417	9	0.8855	0.456949	(9, 22.1)	**0.888**
Null hypothesis: No serial correlation at lags 1 to h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	8.021706	9	0.532	0.903648	(9, 22.1)	**0.539**
2	13.31083	18	0.7728	0.666145	(18, 17.5)	**0.801**

Table-12: Heteroskedasticity test

VEC Residual Heteroskedasticity Tests (Levels and Squares)					
Joint test:					
Chi-sq	**df**	**Prob.**			
52.50829	48	**0.3036**			
Individual components:					
Dependent	**R-squared**	**F(8,10)**	**Prob.**	**Chi-sq(8)**	**Prob.**
res1*res1	0.493821	1.219482	0.3769	9.382597	0.3111
res2*res2	0.157782	0.234176	0.9746	2.997857	0.9345
res3*res3	0.227775	0.368699	0.9147	4.327721	0.8264
res2*res1	0.238424	0.391332	0.9016	4.530048	0.8064
res3*res1	0.288452	0.506732	0.8263	5.48058	0.7052
res3*res2	0.17393	0.263189	0.9646	3.304669	0.9138

This is the graph of co-integrating relation when the target variable is LNCO2 and the explanatory variables are LNGSDP and LNENE (See figure 3).

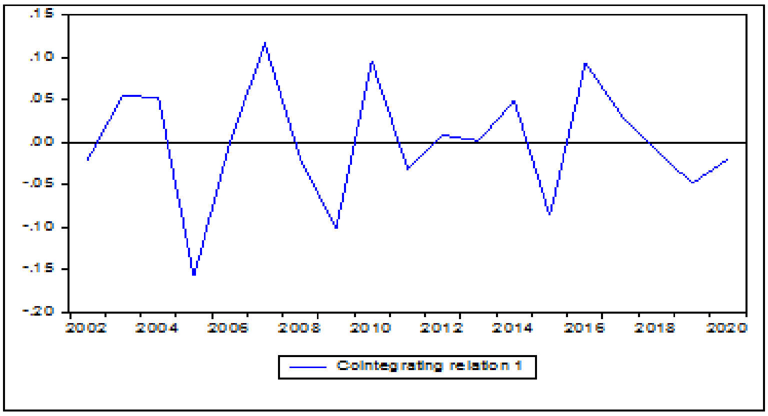


Figure-3: Co-integrating Relation-1 Graph

When LNCO2 is the dependent variable. And the explanatory variables are LNGSDP and LNENC. The existing model is stable at 5% level of significance which is good enough for our model (See figure 4).

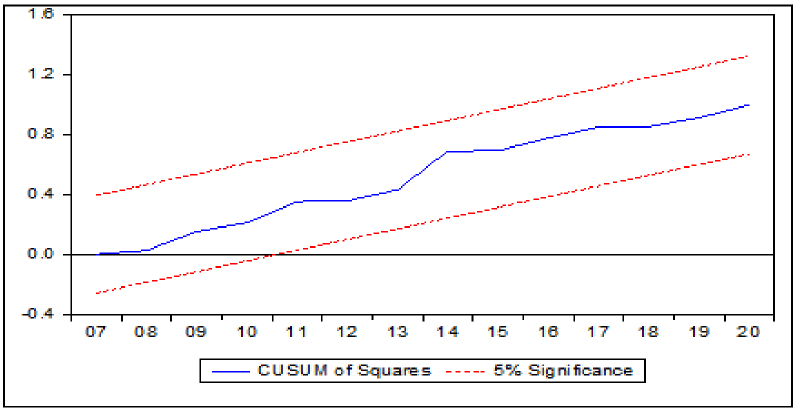


Figure-4: Square of CUSUM test

Table-13: Quadratic EKC Regression Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GSDP	5.550092	1.190454	4.662166	0.0002
SQ_GSDP	-1.01E-07	3.95E-08	-2.552881	0.02
C	-14461454	8027786	-1.801425	0.0884
R-squared	0.916059			
F-statistic	98.2188			
Prob(F-statistic)	0			

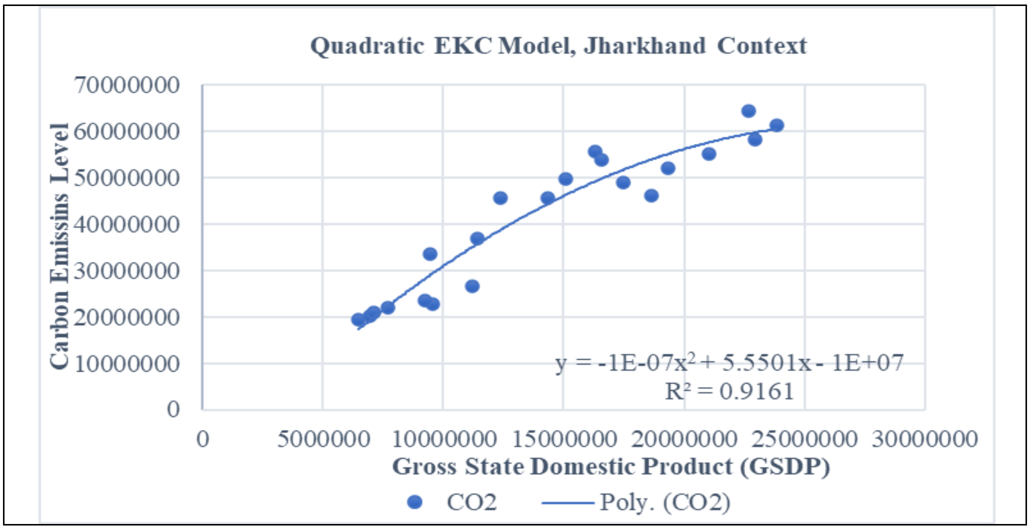
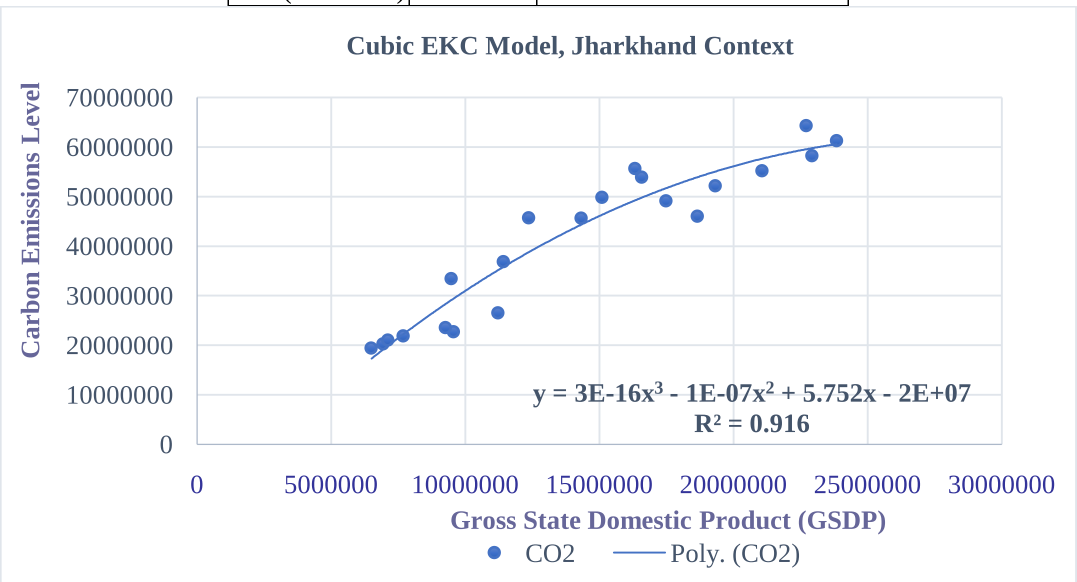


Figure-5: Plotting of the Quadratic EKC Regression Model

Table-14: Cubic Environmental Kuznets Curve Regression Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GSDP	5.752551	5.928421	0.970335	0.3455
SQ_GSDP	-1.15E-07	4.19E-07	-0.275687	0.7861
C_GSDP	3.21E-16	9.21E-15	0.034904	0.9726
C	-15309146	25652853	-0.596781	0.5585
R-squared	0.916066			
F-statistic	61.8463			
Prob(F-statistic)	0			



Finally, the CO_2 emissions level was regressed on explanatory variables real GSDP. Based on the quadratic EKC model regression result the expected sign of the co-efficient of GSDP and the co-efficient of square of GSDP was found to be positive and negative respectively and both are statistically significant which leads to there is an inverted U-shaped EKC (Table 13). The regression line represented in the chart with regression equation and their co-efficient values (See figure 5). As per result of cubic EKC model regression indicates that the expected sign of GSDP was found to be positive, co-efficient of square GSDP was found to be negative and co-efficient of cubic of GSDP was positive but all are statistically insignificant (Table 14). This leads us there is no existence of Environmental Kuznets Curve in this context. It may be cubic curve or N-shaped curve. The regression line represented in the chart with regression equation and their co-efficient values (See figure 6).

5. FINDING AND CONCLUSION

In this paper the analysis is done for finding the long run and causal relationship between the carbon emissions level, real GSDP, and energy consumption based on the available data for the period 2000-2020. As per results of ADF test, all the selected variable are stationary at 1st difference with intercept and trend at 5% level of significance. After this, the Johanson system co-integration test was performed to confirm that there is a long run relationship or co-integration between the variables CO2, real GSDP and ENE. As per results of this co-integration test, there is a co-integrating vector which means that the selected variables are co-integrated. Next, we estimate VECM for the validation of long run relationships among the variables. As per result, the long-run equilibrium relationship indicates that with no change in energy consumption, an increase in GSDP causes an increase in carbon emissions level and with no change in GSDP, an increase in energy consumption causes an increase in carbon emissions level. The coefficient of ECT_{t-1} was found to be -2.1. This means that deviation from long run relationship is corrected at the rate of 2.1 percent in this period. The VEC Granger Causality/Block Exogeneity Wald Tests is used to check for the existence unidirectional and bi-directional causality among the variables. As per results, the real GSDP does causal effect on both carbon emissions and energy consumption which means that a unidirectional relationship between the real GSDP and both carbon emissions and energy consumption. As per result of Wald test, there is presence of short run causal effect between the variables. Also, by some residual test the residuals are not normally distributed, residuals are not serial correlated and the residual series is homoscedastic. Based on square of CUSUM test model is stable at 5% level of significance. Lastly, to test the existence of EKC we perform the regression analysis between the variable CO2 and real GSDP. As per result of the regression analysis the quadratic form EKC model indicates that there is an inverted U-shaped curve in Jharkhand EKC context which is statistically significant at 5% level of significance. As per result of the cubic regression of EKC model implies that there may be N-shape curve in Jharkhand. So, it is important to take necessary decisions in helping the state move towards energy efficiency in order to reduce the carbon emissions level.

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